RIVETS

THE S. SEVERANCE MANUFACTURING CO.
GLASSPORT
PENNSYLVANIA

RIVETS

Standards in the Application of RIVETS as fasteners in Boiler, Structural and Ship Construction

SEVERANCE STANDARD STAMP

It has been our experience in dealing with Engineers, Purchasing Agents, and other representative men in industry, that they are laboring under the disadvantage of not having their data in relation to standards for Rivets and Riveting in one volume. The use of Rivets as fasteners has generally been looked upon as an abstruse subject. There are no hand books devoted exclusively to Rivets, with standard specifications, rules and tables therein, and accordingly we are issuing this volume hoping that it will fill a need, and become a serviceable book for persons engaged in the design of riveted joints, the purchase of rivets, and for the man actually driving this type of fastener.

THE S. SEVERANCE MANUFACTURING COMPANY,

Glassport, Pennsylvania.

Established 1828.

First Edition.

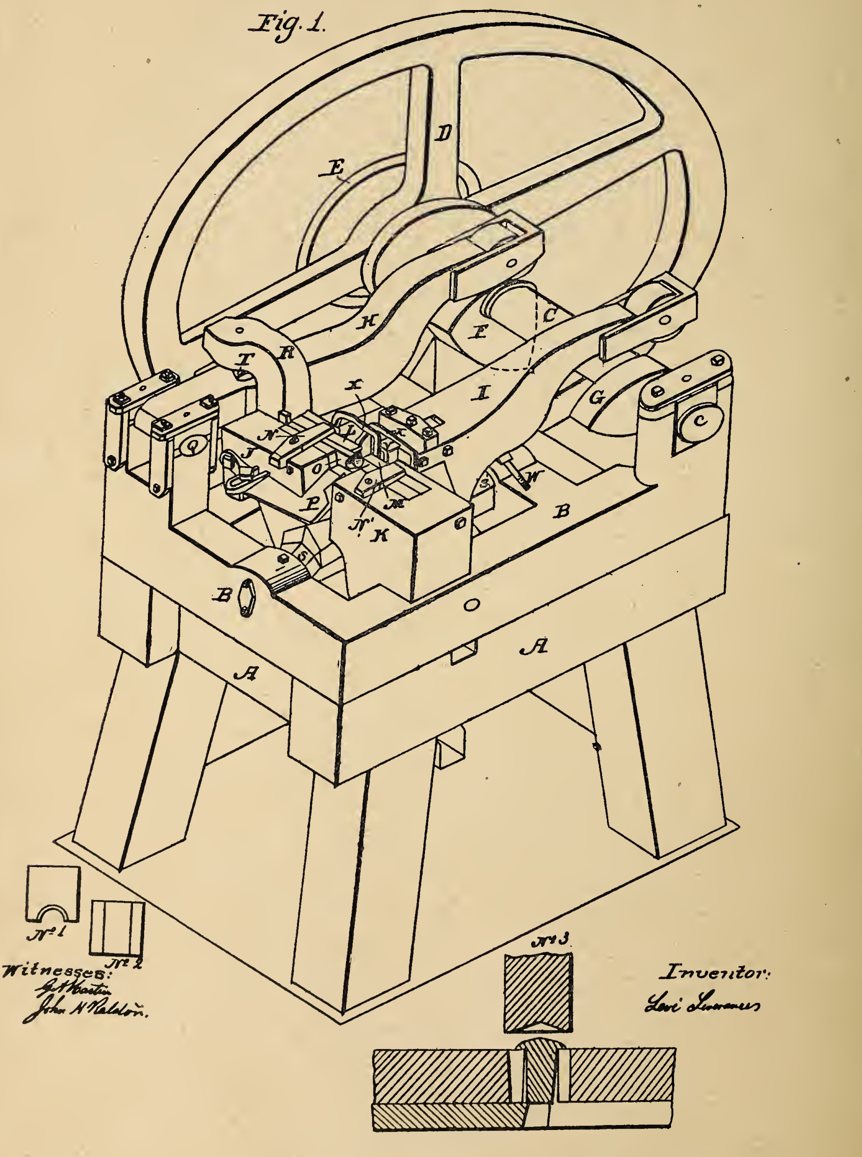
THE S. SEVERANCE MANUFACTURING COMPANY

L. SEVERANCE.

Machine for Making Bolts.

No. 268.

Patented July 11, 1837.



Cut 3.
The patent issued on the first American Bolt and Rivet Making Machine.
Granted to the founder of this Company in 1837.

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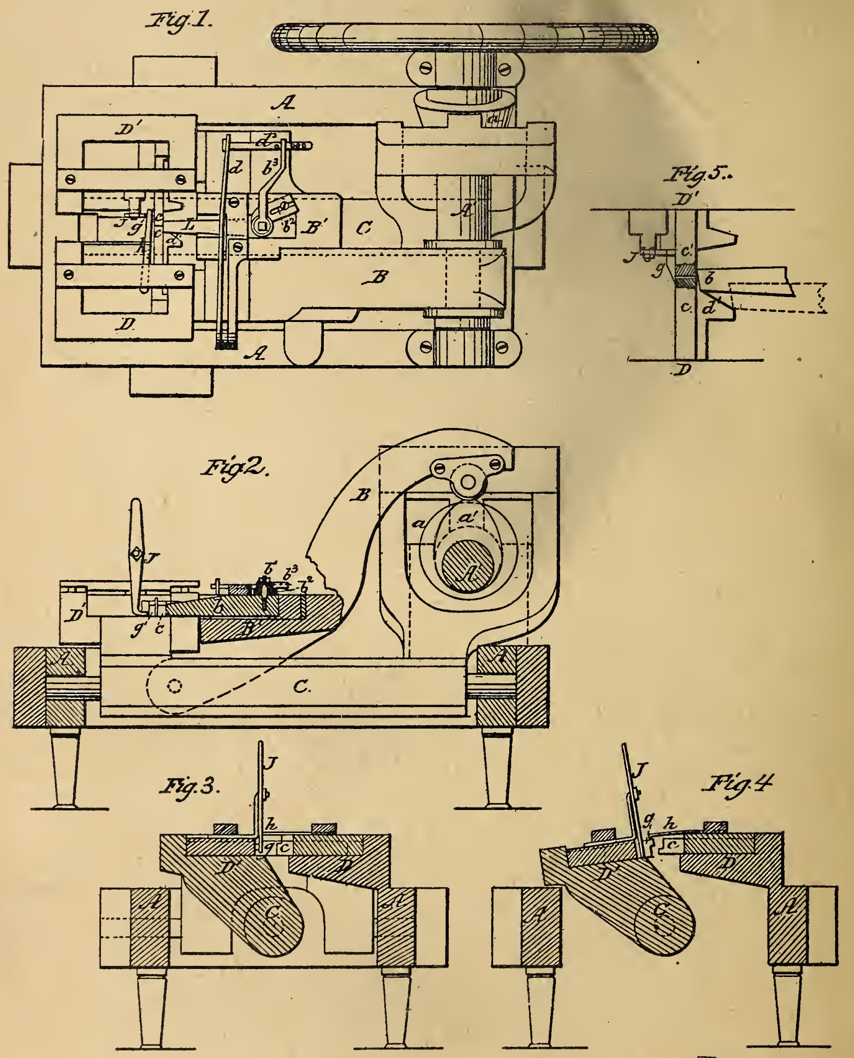
THE S. SEVERANCE MANUFACTURING COMPANY

S. SEVERANCE.

Spike and Rivet Machine.

No. 43,712. Patented Aug. 2, 1864.



Witnesses
R. T. Campbell
Eckhofer.

Inventor.
Samuel Severance
by his attys.
Mason Fenwick & Lawrence

N. PETERS. Photo-Lithographer, Washington, D. C.

Cut 4.

Another basic Patent issued to this Company on Machinery for Rivet Manufacture.

CHAPTER I.

EARLY HISTORY OF THE RIVET INDUSTRY

The S. Severance Manufacturing Company have been manufacturing rivets since 1828—almost for a century. The business was founded by L. Severance who had, previous to that time, invented a rivet making machine. We were unable to obtain a copy of the first patent, which would have been numbered among the very first patents issued by the United States Government, due to the destruction of Patent Office Records by fire many years ago. On page 2 we illustrate the Patent Drawings of Patent 268 granted to L. Severance in 1837, covering other ideas of the founder of this Company on machinery for the manufacture of Bolts and Rivets.

L. Severance located in Pittsburgh in what is now known as the Point District and continued the business until his death in 1854, being succeeded by his son, Samuel Severance, who carried on the manufacture of Spikes and Rivets under the name of S. Severance in the original plant in the Point District until October, 1899. A more advantageous location for manufacturing was found in Glassport, Pa., at this time and the plant was moved. At the death of S. Severance, in 1900, the business was continued by his sons under the name of S. Severance, a copartnership, and on May 23d, 1902, the company was incorporated under its present name, The S. Severance Manufacturing Company.

During the early days of manufacture, the machines developed by L. Severance were used in addition to making rivets, to make spikes, bolts and other articles in a more or less crude and small way. Then the requirements of the country were small and the product then turned out earned a reputation for quality and workmanship. Wrought iron was used entirely in the manufacture of rivets until about 1887, when soft steel was investigated and after numerous experiments and the surmounting of a great many discouraging obstacles, it was decided to use Dead Soft Steel exclusively in the manufacture of our Boiler Rivets. During the years 1890 to 1895 we advertised and exploited very strongly the "S.S." Soft Steel Boiler Rivet, and the missionary work that accomplished such good results were vigorously carried on. We were the first company to put on the market a Soft Steel Boiler Rivet and to sell it as such. We used a very special grade of Dead Soft Steel that was made under the most rigid inspection and our rivet was the only Steel Boiler

Rivet that was equal to the service that Boiler Rivets entered into at that time. It took much educational work and strong salesmanship to establish the place of the Steel Rivet, the consumer gradually coming to understand its use and finally adopting it, so that now all rivets are made of Open Hearth Steel, with but few exceptions.

We have continually tried to improve quality and workmanship and have readily adopted any process or material that would tend towards the making of a superior grade of rivets.

Our plant, located at Glassport, 18 miles above Pittsburgh on the Monongahela River, is one of the most modern in the world and every facility and advantage that tends towards the manufacture of good product is there. Our proximity to Pittsburgh gives us many advantages, such as the best Soft Steel, Natural Gas for heating rivet stock in manufacture, and the most skilful labor.

CHAPTER II.

STEEL

Steel is an artificial complex substance lying between carbonless wrought iron on one hand, and high carbon iron or cast iron on the other hand. Its chief characteristics in comparison to wrought iron is its freedom from slag and greater homogenity, while in comparison to cast iron it possesses properties due to physical and structural condition vastly different from cast iron. The properties of steel are due to its internal chemical composition. Steels are graded according to the amount of carbon that they contain, and a tabulation is as follows:

Dead Soft Steel	Carbon not over	.12
Low Carbon Steel	Carbon not over	.25
Medium Carbon Steel	Carbon from	.26 to .60
High Carbon Steel	Carbon above	.60
High Carbon Tool Steel	Carbon above	1.25

As a chemical compound steel is composed of relatively pure iron and iron carbide. Iron carbide is the substance formed by the carbon in the steel uniting chemically with iron to form a chemical compound Fe_3C, and which is the substance that gives steel its characteristic properties. The more the carbon present the greater the amount of iron carbide, hence sensitiveness to heat treatment, hardening, etc., while the less the carbon the less the amount of iron carbide present and the approach to pure iron, with the added desirability of freedom from slag, and possessing great homogenity and ductility. The other constituant in steel, relatively pure iron, cannot be considered absolutely pure, as other compounds are formed by Manganese, Silicon, Sulphur and Phosphorous, and existing as impurities being held in solid solution in the steel. Excessive amounts of any of these impurities cause undesirable properties in steel.

For rivet making, steel should be as low in carbon as possible, but not under .08, and low in all impurities, but possessing great homogenity and ductility. In order to understand the effects of the impurities and other ingredients in steel the following should be noted.

CARBON

The general effect of carbon in steel is to give it great tenacity. The tensile strength is increased approximately 6000 pounds per square inch for each increase in .10 carbon. A steel with .10 carbon content will show a tensile strength of approximately 50000 pounds per square inch, while a steel having 1.00 carbon content will have a tensile strength of approximately 100,000 pounds per square inch. Steel with .20 carbon content begins to show an appreciable hardening effect when heated to the critical point and cooled quickly. In the normal state steel does not show evidence of brittleness until .70 carbon content is reached. With increase in carbon content the elongation or ductility of steel decreases.

MANGANESE

The strength and the elastic limit in low carbon steels are increased to a certain extent by Manganese. Manganese effects a resistance to shock. It counteracts the red shortness in steel caused by Sulphur. Manganese is added to steel after tapping from the Open Hearth Furnace in the form of Ferro Manganese, and it performs the function of absorbing oxygen in the molten steel. It also prevents to a large extent the coarse crystalization in steel due to sulphur and other impurities. Steels low in Sulphur and Phosphorus require less Manganese than those containing higher amounts . Manganese gives to steel the property of hot ductility. It is, however, advisable to keep the Manganese as low as possible, but not under .30, and at the same time producing a sound steel and one that will roll properly. In steel the maximum temperature to which it may be reheated is increased by Manganese, owing to the resistance of Mangnese to the separation of the steel crystals when the steel is again cooled. Manganese increases the tensile strength of steel in proportion to the carbon content. For a .35 Manganese steel add 650 pounds per square inch to the tensile strength for a .10 Carbon steel, and add 100 pounds per square inch to this base figure for each increase in .05 carbon. Thus for a .40 Carbon, .35 Manganese steel, the addition would be 1250 pounds per square inch to the tensile strength of the .10 Carbon steel. For each increase of .05 Manganese above the base .35 Manganese, add 650 pounds per square inch to the base 650 of the .35 Manganese steel, and also add the 100 pounds for each .05 carbon. Thus for a .60 Manganese, .40 Carbon steel the addition would be 4500 pounds per square inch.

SULPHUR

Excessive sulphur causes steel to crack and tear in rolling or in hot working, and the term "Hot or Red Shortness" has been applied to describe this effect. High sulphur lessens the welding capacity. Manganese has a high chemical affinity for sulphur, forming Manganese Sulphide in molten steel. Manganese Sulphide segregates and collects between the steel crystals, and thus produces seams, if present in excessive amounts. Red Shortness is probably caused by this Manganese Sulphide which has a lower melting point than steel itself, and thus in hot working or rolling the Manganese Sulphide may melt, reducing the cohesion between steel crystals to such an extent as to cause cracks and tears. Sulphur in steel ranges from .020 to .100, the higher figure being used for steel to be used in Automatic Screw Machines, and known as Screw Stock, a steel of good machining qualities but otherwise poor. It is customary to specify steel with sulphur not over .050. Sulphur increases the tensile strength but little, each .010 increases in sulphur content increasing the tensile strength approximately 500 pounds per square inch.

PHOSPHOROUS

Excessive Phosphorous causes a coarse crystalization in steel. It causes no trouble in rolling, but in the cold state and subject to sudden shock or vibration high phosphorous steels break very easily. The lower the temperature and the higher the phosphorous in steel the more brittle

the steel, hence the term "Cold Shortness" has been applied to denote this property. High carbon intensifies this bad effect due to the high phosphorous. Phosphorous reduces the elongation and the ductility of steel, and while not so apparent in the usual tension test, is very pronounced in vibratory or impact testing machines. All steels should be as low in phosphorous as possible, it being usual to specify .040 or under. The apparent increase in tensile strength of steel due to phosphorous amounts to approximately 100 pounds per square inch for each increase in .001 of phosphorous, this being for steels up to .12 carbon content. For steels from .12 to .25 carbon the increase amounts to 150 pounds per square inch for each increase in phosphorous of .001.

COPPER

The chief effect of copper is to cause Red Shortness, and over .50 to effect the welding power of steel. Copper and high sulphur in combination produce bad effects. If sulphur is low, no bad effects from High Copper are manifest, and Copper Bearing Steels are advocated for anti-corrosion properties. Copper causes no physical changes as usually measured. Copper is not usually present in Rivet Steel.

ALUMINUM

The tensile strength of steel is only slightly affected by aluminum, and the ductility is not diminished. When used to quiet steel a very little of the aluminum combines with the steel itself. The quantity of aluminum used to quiet steel when casting amounts to from $\frac{1}{8}$ to $\frac{3}{4}$ of a pound per ton of steel, the amount used varying with the grade of steel, the amount of occluded gases in the molten steel, and the temperature of the molten steel. Aluminum is added in the steel ladle directly after tapping, and often in the moulds, being added to the molten steel teeming into the moulds to prevent blow holes and to reduce segregation. Aluminum increases soundness in ingot tops, kills wild heats, prevents oxidation, and increases the tensile strength by inducing homogenity in the steel. Excessive amounts of aluminum causes excessive pipe, and should be avoided, and excessive additions of aluminum added to the moulds is harmful due to the probability of aluminum oxide agglomerating with the steel, and thus weakening it. Aluminum is not determined in the usual chemical analysis of steel.

SILICON

Silicon tends to remove occluded gases and oxides from steel, and thus prevents blow holes, yielding homogenity, soundness and toughness. It increases the tensile strength and reduces the ductility. Silicon neutralizes the injurious tendencies of Manganese, and steels containing Silicon are better able to stand wear and crushing from continual pounding. The usual amount of silicon present in structural steels amounts to .025 and is not usually reported in the chemical analysis of such steels.

NICKEL

Nickel in steel increases its strength, ductility, toughness and resistance to abrasion and shock. It also increases the ratio of elastic limit to tensile strength. Nickel steels are made by adding Ferro Nickel or Nickel Ore to the Open Hearth steel bath. Ordinary Nickel Steel is a low carbon steel, containing under .40 carbon and up to 3.50 nickel. The welding power of Nickel Steel decreases with increase in nickel content, but nickel steels all forge well. An addition of 2.00 nickel to a steel will increase its strength to nearly double that of a simple carbon steel, of the same carbon content. This increase in strength is however dependent on proper heat treatment for this result.

CHROMIUM

Chromium added to steel increases the elastic limit, hardness and resistance to shock and alternate stress. It is a very fine grained steel and is principally used in steels to be heat treated. Chromium tends to reduce crystaline growth. In the rolled or forged condition Chromium Steels are like plain carbon steels of like carbon content.

TUNGSTEN, MOLYBDENUM, VANADIUM

Tungsten, Molybdenum, Vanadium, and other rare metals added to steel, provide particular properties, but are never used in the production of structural, boiler, or steels required for Ship construction. Their field is found in tools, machine parts, and their properties are developed through heat treatment.

MANUFACTURE OF STEEL

Practically all of the steel used for rivet manufacture is made by the Basic Open Hearth process. Open Hearth heats are made containing as high as 200,000 pounds of metal in a single heat. In this process steel and pig iron are melted in a furnace operating on the regenerative method of burning fuel. The melted metal is worked down to a low carbon content by adding iron ore to the bath, and a slag high in lime is produced to remove phosphorous from the metal charged. The oxygen in the iron ore burns out the carbon in the molten metal, producing a practically pure melted iron, but one heavily charged with oxygen and gases. Molten steel dissolves gases similar to the manner in which water does, but when steel solidifies and cools these gases pass off. In order to insure of perfect degasification, and to regulate when and how the gases pass off, Ferro Manganese is added to the Open Hearth heat, either in the furnace directly before casting, or in the ladle. A worked down heat will contain .05 carbon, .05 manganese, .030 sulphur, and .030 phosphorous, and after the addition Ferro Manganese it will be .10 carbon, .45 manganese, .040 sulphur, and .030 phosphorous. The quantity of Ferro Manganese added to a dead melted Open Hearth heat containing 50 tons of molten metal will amount to approximately 300 pounds, this in order to yield a steel with a manganese content of from .30 to .40. Ferro Manganese also adds carbon to the steel and 5% of the total weight of Ferro Manganese added

can be relied upon as entering the steel as carbon. When high carbon steels are made the carbon is added through the use of Molten Pig Iron which is added to the dead melted steel in the furnace, and the furnace immediately tapped. Approximately 3% of the weight of Molten Pig Iron added as recarburizer appears in the steel as carbon. Observed temperatures of steel flowing from an Open Hearth furnace are approximately 3000 Fahrenheit.

Steel for rolling of structural shapes is usually cast in large size open top moulds, and "killed" during the pouring by the addition of aluminum. This treatment removes blow holes, and limits segregation. Steel fcr plates is also top poured into moulds and the "Riming In," taken particular note of, in order that the blow holes shall be at least $\frac{3}{4}$ inch from the walls of the resulting ingot. In the manufacture of steel for rivets, this soft steel is likewise cast in open top moulds, and properly "Rimed In," to produce deep seated blow holes. The steel must be properly worked in the furnace, the slag must be in good condition, and the temperature correct, otherwise on tapping the steel will rise in both the ladle and in the moulds, and not properly "Rim In." This follows for both a sluggish cold steel, and for one that is too hot, and blow holes very near the surface of an ingot would result. When such a steel is rolled these blow holes near the surface are forced through the surface, become oxidized, and in rolling greatly elongated, producing surface defects such as slivers, scabs, cracks, seams, and laminations. If the blow holes are deep seated and approximately $\frac{3}{4}''$ inside the surface, and if they are clean and free from slag and oxides they weld perfectly in the rolling and slabbing and cause no trouble. In plates in particular, surface defects are common on account of the great reduction from slab to plate, and the great surface area exposed, and care in steel making is highly important.

All steel will pipe more or less in the process of cooling, and cropping of the head is the only way of eliminating this defect. The specification of a certain amount of crop in per cent. is not always correct as different steel mills have a range in skill, those having the greater skill will produce sound steel with a small amount of cropping to remove pipe. The effect of temperature at pouring, and the effect of aluminum are points to control to produce the minimum pipe. Piping is caused by shrinkage due to the cooling of the steel in the ingot, and results in cavities arranged along the central axis of the ingot. It is always present at the top of the ingot, known as primary piping, or further down in the body of the ingot, known as secondary piping. Piping may appear in the rolled bar as a small hole, sometimes large enough to be seen, but often appearing only as a small dark line, which might be easily taken for a tear in the metal. The cause of such defects is not sufficient cropping.

Segregation is a gathering together of a mass of any one of the elements that make up steel and is usually found in the center of the ingot or rolled bloom, bar or billet. In a fractured specimen it can be detected by the difference in color. Chemical analysis is the sure test for this defect.

The cause of external defects, consisting of seams, laps, folds, slivers, has been mentioned. They may be prevented by chipping out the defects as they appear in the bloom or billet, and prior to rolling into rivet rod.

MECHANICAL WORKING OF STEEL

The steel in ingot form must be shaped, and its structure and physical properties are dependent on the care used in this working, rolling, or forging. The heating and soaking in the soaking pits prior to the first rolling in the bloomer or slabber are important, and each subsequent heating and rolling must be done with intelligence and care. The finishing temperature should be done so as to produce a good grained steel. After rolling to shape, or in the case of plate, either universal or sheared edge, the material is straightened. The effect of cold work is not severe and much straightening is done at a fair heat. In the case of Rivet Rounds they are not straightened, but are allowed to straighten from hot bar to the cold undisturbed on a flat hot bed. In the rolling of Rivet Rounds another defect may here appear in Guide Marks, as this material in passing through a continuous mill, is guided between the rolls by cast steel guides which if not properly adjusted may score the red hot bar. In the process of hot rolling it is impossible to produce a perfectly round bar, and for that matter it is impossible to produce a shape precisely to dimensions. Standard dimensions and variations therefrom have been compiled by the Association of American Steel Manufacturers, and which are quoted below.

The Association of American Steel Manufacturers
Adopted 1910

STANDARD ALLOWABLE VARIATIONS IN THE SIZE OF HOT-ROLLED BARS

ROUNDS, SQUARES, HEXAGONS

	Variation in Size Under	Variation in Size Over
Up to and including ½″	.007″	.007″
Over ½″ " " 1″	.010″	.010″
Over 1″ " " 2″	1/64″	1/32″
Over 2″ " " 3″	1/32″	3/64″
Over 3″ " " 5″	1/32″	3/32″
Over 5″ " " 8″	1/16″	1/8″

FLATS

Width of Flats	Variation in Width: Under	Variation in Width: Over	Variation in Thickness, Under and Over — Thickness of Flats: 3/16″ and under	Over 3/16″ up to ½″	Over ½″ up to 1″	Over 1″ up to 2″
Up to and including 1″......	1/64″	1/32″	.006″	.008″	.010″	.....
Over 1″ up to and including 2″........	1/32″	3/64″	.008″	.012″	.015″	1/32″
Over 2″ up to and including 4″........	3/64″	1/16″	.010″	.015″	.020″	1/32″
Over 4″ up to and including 6″........	1/16″	3/32″	.010″	.015″	.020″	1/32″

The S. Severance Manufacturing Company follows closely the Ladle Analysis of all heats of steel entering into the manufacture of their rivets. Our rivets are made to conform to the required Standards and Specifications to which they are purchased, and our mill connections are such that the closest cooperation exists. In addition to certainty of our rivets being to chemical requirements, and to physical specifications, our inspection of Rivet Rounds and Rivet Stock for surface insures our customers of smooth workmanlike rivets. Inspection is made on all of our raw material for seams, slivers, pitting and guide marks, and check measurements for roundness are periodically made, resulting in the production of uniformity in our rivets. Our final inspection of the finished rivet prior to packing into kegs, or sacks, is a double insurance for a perfect product.

CHAPTER III

CHEMICAL AND PHYSICAL TESTS

In order to cover the subject of rivet material completely the following methods of chemical tests are given. Modern chemical analytical methods have reached a high degree of perfection. Correct sampling is highly important.

SAMPLING FOR LADLE ANALYSIS

A sample of the steel from the ladle after tapping from the Open Hearth Furnace is taken by means of a hand ladle, and this cast into a small test ingot. Drillings are made in this test ingot by using a drill ½″ to ¾″ in diameter, the drill carefully operated without application of water, oil, or any cooling lubricant. Care is taken that no dirt, scale, grease or any foreign matter gets mixed with the drillings.

CARBON

Carbon in steel is determined by two methods, the color method, and the combustion method. The color method is an approximation while the combustion method is exact, but for low carbon steels under .35 carbon the color method is found to closely agree with the combustion method In case of controversy the combustion method should invariably be used.

COLOR METHOD

In determining carbon by the Color method, 0.5 grams of the steel drillings are placed in a large test tube, and 10 cc of dilute Nitric acid (50%) added. At the same time 0.5 grams of a standard steel of known carbon content, which has been determined by the Combustion method are placed in another test tube and 10 cc of dilute 50% Nitric acid added. Both test tubes properly marked are placed in a Water bath and boiled gently until the steel is dissolved. When the solution is complete both test tubes are removed from the Water bath and placed in cold water. Both solutions are now diluted to the same volume, vis 50 cc, and compared in color in a colorimeter. Dilute the most intense in color until the color in both tubes is the same. The carbon content in the steel being analyzed is directly proportional to the dilutation made.

COMBUSTION METHOD

In the Combustion method, 2.0 grams of fine Steel chips are packed on a bed of Alundum, in a porcelain or nickel boat. The boat and contents is transferred into the combustion tube of a Carbon train, previously heated to approximately 1800° F, the tube being of porcelain, quartz or platinum. After a lapse of about one minute the boat is up to the temperature of the tube, when oxygen of 97% or higher purity is admitted, so that the chips burn completely, but not violently. The burning is complete in two minutes at the most, and the Carbon Dioxide produced is swept out

into a Meyer tube containing a saturated solution of Barium Hydrate, by admission of about 2 liters of oxygen in not more than 6 minutes. In charging the Meyer tube, four bulbs are filled with Barium Hydrate solution, and then water free from CO_2 added to fill the remaining three or four bulbs in the tube to the proper level. The Meyer tube is then detached, fastened to a filter, and the Barium Carbonate filtered onto an Asbestos pad. Connection is so made that the Meyer tube is washed, some 150 cc of Wash water being used. The Filter pad is transferred to a Flask, and the filter carefully washed, an excess of N/10 Hydrochloric acid added from a pipette. 3 drops of Methyl Orange indicator (2%) are added, and the excess acid titrated against N/10 Sodium Hydrate. The carbon is calculated, 1 cc N/10 HCL being equal to 0.0006 gr. carbon.

MANGANESE IN STEEL

1.0 grams of the drillings is placed in a 200 cc flask, and 50 cc of Dilute Nitric acid (18%) added. The flask is heated until the steel is all dissolved and oxides of Nitrogen driven off. The solution is then cooled and 0.5 grams of Sodium Bismuthate added to oxidize all carbon. The contents of the Flask is then heated until the pink coloration disappears. Sulphurous acid is added until the solution is clear, and then boiled to expell all surplus Sulphurous acid. The solution is then cooled to room temperature, and an excess of Sodium Bismuthate added (2 to 3 grams), and agitated for several minutes. Add 50 cc Dilute Nitric acid (3%), and filter through asbestos into a 300 cc flask. Wash the asbestos well with cold 3% Nitric acid. Run into the filtrate 50 cc of standard Sodium Arsenite, or sufficient to discharge the pink coloration of the permanganate solution. The titrate back to just pink by a standard solution of Permanganate. Having this determined the number of cc of standard Sodium Arsenite required to react the Manganese in the sample, calculate the percentage of Manganese in the steel. Speed can be obtained by making the standard Sodium Arsenite solution so that 1 cc is equivalent to 0.10% Manganese in the 1.0 gram sample taken.

SULPHUR IN STEEL

Take 5.0 grams of the steel drillings and place in a flask fitted with a two-hole stopper. Through one hole in this stopper there passes a thistle tube, and through the other a delivery tube. The delivery tube connects with a smaller flask containing Ammoniacal Cadmium Chloride solution. The Hydrogen Sulphide evolved is absorbed by the Cadmium Chloride, and 10 cc of Cadmium Chloride, diluted with 150 cc of water should be contained in the absorption flask. Pour through the thistle tube into the flask, 80 cc of dilute Hydrochloric acid. Warm the flask so that the steel dissolves rapidly. Boil for about ½ minute, until all the volatile Sulphur Compounds have been passed over into the absorbant Cadmium Chloride. Empty the Cadmium Chloride solution into a 500 cc beaker, carefully washing out all values. Add 5 cc of Starch solution and 40 cc of dilute Hydrochloric acid, to just render the solution acid and dissolve the Cadmium Sulphide. Stir gently, and titrate at once with Standard Potassium Iodate solution to a blue end point. The Standard Iodate solution is so made that 1 cc equals .0005 grams of Sulphur. As a

5 gr. sample was taken, each 1 cc of this Standard represents .010 Sulphur in the steel. Thus the number of cc of Standard Potassium Iodate required to the end point times .010 equals the Sulphur content in the steel.

PHOSPHOROUS IN STEEL

Take 5 grams of the steel drillings and place them in a 300 cc flask. Add 75 cc of Dilute Nitric acid (50%) and warm, finally bringing to a boil. While still boiling add 12 cc of Potassium Permanganate solution ($2\frac{1}{2}$%) and heat until Manganese Dioxide precipitates. Add Ammonium Bisulfite solution (3%) to dissolve this precipitate and boil until clear and brown fumes cease to come off. Cool to room temperatures, and add 100 cc of Ammonium Molybdate solution. Shake for 3 minutes and filter and wash three times with Nitric acid (2%). Wash the precipitate with Ammonium Hydrate (10%), filtering into a 150 cc beaker containing 10 cc of Hydrochloric acid (39%) and 0.5 grams of Citric acid. Add 30 cc of Ammonium Hydroxide (28%), cool and then add 10 cc of Magnesium Chloride mixture, slowly and with agitation of the solution. Stand for two hours, filter, and wash with Ammonium Hydroxide (10%). Ignite and weigh. Redissolve in 5 cc of Nitric acid (32%) with 20 cc water, filter and wash with warm water. Ignite and weigh. The difference in the two weights represents pure Magnesium Pyrophosphate, containing 27.84% Phosphorous.

SAMPLING FOR CHECK ANALYSIS

Correct sampling for check analyses are as important as requirements for Ladle analysis. In order to standardize the methods the Association of American Steel Manufacturers have prescribed methods, which are quoted in toto below.

THE ASSOCIATION OF AMERICAN STEEL MANUFACTURERS

Adopted 1912.

MANUFACTURERS' STANDARD PRACTICE.

STANDARD METHODS OF SAMPLING FOR CHECK ANALYSIS

INTRODUCTION

It is a recognized fact that the different parts of a piece of steel are liable to vary in composition. This variation occurs principally between the center and the outside, and to a slighter extent is dependent upon the position of the piece in the ingot, and the size of the ingot.

Where a sufficient number of check analyses have been made from drillings properly taken at different points in the heat to represent it fairly, their average has been found to compare favorably with the ladle analysis, which is the analysis of a small test ingot taken at any time during the pouring of the heat.

From this it is evident:

1. That the ladle analysis is more representative of the composition than any single analysis of the finished material.

2. That drillings for check analysis to be fairly representative should be taken at a point intermediate between the outside and the center of the cross-section.

3. That a sufficient number of check analyses of different pieces should be made to afford a fair average to compare with the ladle analysis.

1. POINTS TO BE OBSERVED IN THE SAMPLING OF MATERIAL FOR CHECK ANALYSIS.

a. Each heat in a lot shall be considered separately, and pieces for sampling shall be taken to represent the heat as fairly as possible.

b. Samples must be drillings or chips cut by some machine tool without the application of water, oil or other lubricant, and shall be free from scale, grease, dirt or other foreign substance. If samples are taken by drilling, the size of the drill shall not be not less than $\frac{1}{2}''$ nor more than $\frac{3}{4}''$ in diameter.

c. Samples must be uniformly fine and each must be carefully mixed before analysis.

d. In referring samples to the manufacturer or other analysts for check analysis, a piece of full-size section, when possible, should be submitted rather than cuttings, unless the latter are specially requested.

e. Where material has been subjected to heat treatment other than annealing or simple cooling, subsequent to its manufacture, it should be annealed before sampling.

f. Check analyses are not representative of the original material when its composition has been altered in any way by some operation such as case-hardening, overheating, etc.

2. METHODS OF OBTAINING SAMPLES FOR CHECK ANALYSIS.

Material has been divided into the following classes, depending upon the manner of sampling.

I. Material Subject to Physical Requirements.

Samples for check analysis shall be taken from a test specimen. Where it is required to make additional check analyses, samples shall be as indicated under II.

II. Material Not Subject to Physical Requirements:

(a.) Special cast, rolled or forged, semi-finished or finished material of large size, such as ingots, blooms, billets, slabs, rounds, shapes, etc., subject to acceptance on check analysis.

Samples shall be taken at any point midway between the outside and the center by drilling parallel to the axis. In cases where this method is not practicable, a piece may be drilled on the side, but drillings shall not be taken until they represent the portion midway between the outside and the center. See Figure 1.

(b). Small or thin material, such as plates, shapes, bars, etc., subject to acceptance on check analysis.

Material for which the previous method is not applicable shall have samples for analysis taken entirely through the material at a point midway between the outside and the center, or by machining off the entire cross-section.

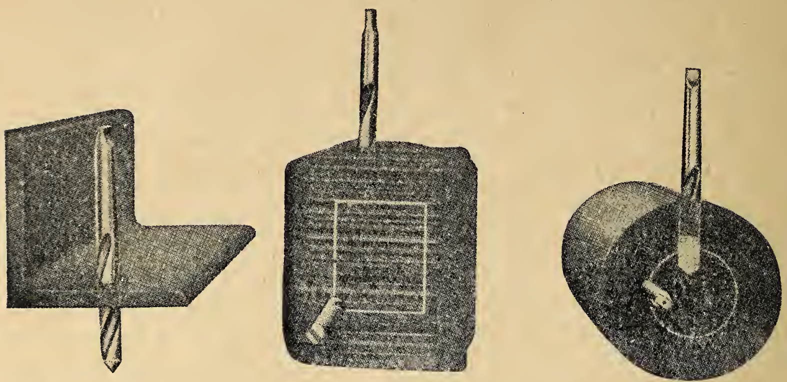


FIG. 1 Cut 5.

(c). Commercial material subject to acceptance on ladle analysis.

The methods described under II (a) and (b) shall apply, except that samples shall be taken at any point one-third of the distance from the outside to the center.

3. METHODS OF ANALYSIS.

Analysis shall be made by well-known accurate methods. Carbon shall be determined by the combustion method.

4. REJECTION OF MATERIAL ON CHECK ANALYSIS.

Any rejection of material ordered to a specific chemical range shall be based on the following:

(a.) The minimum number of samples to be taken from a heat before rejection by the purchaser shall be as follows:

Weight in Gross Tons.	Minimum Number of Samples.
5 or less	3
10 or less but over 5	4
15 or less but over 10	5
Over 15	6

In case the number of pieces in a heat is less than the number of samples given, one sample from each piece shall be considered sufficient.

(b). Separate determinations shall be made on each sample and the results averaged, unless they clearly indicate mixed grades.

PHYSICAL TESTING

Testing to destruction is the supreme test of strength of any material. In order to judge whether a metal is suitable for the purpose for which it is intended, test pieces are selected and upon the results of these tests the metal is judged as a whole. Chemical analysis is not conclusive in itself and accordingly physical tests are usually made on steels conjunctively with the chemical tests. In physical testing determinations are regularly made on a Tension machine, the tensile strength, elastic limit, elongation,

and reduction of area being the points usually recorded. In addition to these tests, compression tests, torsional tests, shearing tests, deflection tests, and endurance tests are sometimes made for special purposes.

THE TENSILE STRENGTH, sometimes called the ULTIMATE STRENGTH, is the load per unit of original cross section at which rupture occurs. As the load is applied to a specimen and it increases in length, a diminutation of cross section likewise occurs. At the time of rupture considerable "Necking In" may take place, but this reduced area should not be used in calculating the Tensile strength of the material. Tensile strength is recorded in pounds per square inch breaking stress.

THE ELASTIC LIMIT, as made in commercial tests of Structural material is not the true Elastic limit, but is the YIELD POINT. The Elastic limit is properly obtained by means of an Extensometer, and the load applied by increments of 5000 pounds until the Elastic limit is nearly reached, and then by increments of 1000 pounds. Readings of the Extensometer are taken after each imposed load. As soon as stress and strain are out of proportion the Elastic limit is reached. Such a process of testing is very slow and not one that could be used in testing large quantities of RIVET steel, Structural steel or plates. The YIELD POINT is defined as the load per unit of original cross section at which a marked increase in the deformation of a test specimen occurs without an increase in load. It is usually determined by the drop in the beam of the testing machine, or by the use of dividers. In using the dividers, the divider points are placed in the punch marks used for elongation measurement, and note taken when the stretch of the material just prevents the points from re-entering the punch marks. This point is the Yield point, and is slightly higher in value than the true Elastic limit. Another method of determining the Yield point and especially true in the testing of Rivet Rounds is as follows: Rivet Rounds are covered with Roll scale, as are all hot rolled products, and just when the test piece begins to deform out of proportion to the load, this Roll scale breaks, and spalls off the test piece, this being a reliable indication of the Yield point.

THE ELONGATION is a measure of ducility. For structural material the elongation is recorded in 8″. Punch marks exactly 8″ apart are made on the test specimen, this being conveniently done by means of a double pointed prick punch with points fixed 8″ apart. Usually two pair of punch marks are made on a bar so that if one set should become illegible the other would serve as a record. After fracture the broken ends of the test piece are matched together and the distance apart of these punch marks measured. For example, after pulling a rivet round the distance will measure 10.5 inches, or 2.5 inches more than the original 8″. The percentage elongation is then recorded by dividing the 2.5″ by 8″ and multiplying by 100, or in this case giving a figure of 31% as the elongation in 8″. Naturally the greater the stretch or elongation the more ductile the material, and the softer the steel.

REDUCTION OF AREA, sometimes called the CONTRACTION OF AREA, is obtained by measuring the smallest diameter of the bar after fracture. This is naturally at the point of fracture, where the "Necking In" was the greatest, and several measurements should be

made to get the correct diameter. The measurements are made by means of a Micrometer Caliper having pointed ends and as the fractured ends are rough, care should be taken to get the correct measurement. In square or oblong pieces this likewise follows, as the departure of rectangular specimens from their original cross sectional shape is more conspicuous than for cylindrical bars.

FRACTURES: Mill practice records the type of fractures as $\frac{1}{2}$ Cup, Cup, or Angular Break. Naturally a Full Cup indicates a very homogenious material, and axial pulling of the specimen. Much good material will fracture $\frac{1}{2}$ Cup, due to the load not being exactly axially applied. Description of fractures are subject to different descriptions by different observers, but the knowledge gained from fracture appearance makes the recording of fractures important.

GRANULAR FRACTURE. This type of fracture is caused by the path of rupture passing through the steel grain boundaries. It is met with in burnt steel.

CRYSTALLINE FRACTURE. This fracture should not be confused with a Granular break, because it is through the crystals and not on grain boundaries. The fracture appears bright, and is usually an indication of brittleness.

SILKY FRACTURE. In this type of fracture the crystals have been drawn out into threads prior to rupture. The Cup and Cone fractures practically all have a silky appearance.

AMORPHOUS FRACTURE. No trace of crystalization is observable, and this fracture is found principally in annealed specimens.

LAMINATED FRACTURE. Fractures of Plate and Structural Shapes will often have laminated structures. They are characteristic of transverse specimens that show some ductility.

THE EFFECT OF SHAPE AND SIZE on the results obtained in testing is governed by KICK'S RULE, which is "under identical conditions of stress, bodies of identical material and of geometrically similar shape, undergo geometrically similar deformation.

SPEED OF TESTING. The rate at which specimens are pulled apart has an effect on the result. The American Society of Testing Materials states that so long as the speed is kept within ranges of from 1 inch to 6 inches per minute, its influence is not observable in the results of commercial testing. If the rate of loading is too rapid it will influence all results giving higher values to tensile strength in many cases.

CALIBRATION OF TESTING MACHINES. Testing machines should be tested periodically to see that they record loads correctly. Machines are calibrated by means of a lever attachment with standard weights.

COMPRESSION TESTS are made in the usual Tension machine, by using a compression attachment, which consists of a spherically seated lower

block, which allows the load to be applied axially, and a rigid face block that is attached to the pulling head of the Tension machine. By reversing the machine the load is applied to a specimen. Elastic limit and Final failure are usually recorded.

SHEARING STRENGTH is obtained by using a shearing tool in the usual Tension machine, and which consists of a block with knives and a specimen rest that is placed on the table of the Tension machine. The pulling head of the Tension machine is fitted with a crushing tool and which forces a knife through the specimens being tested. For double shear recording two lower knives are placed in the lower block exactly 1″ apart, while the upper knife is exactly 1″ wide, and shaped to conform to the shape of the specimen, vis half round for testing a round specimen. Shearing value is approximately 2/3 the Ultimate Tensile Strength, for specimens in single shear, while for specimens in double shear it is double that value.

TORSIONAL TESTS are made in a special machine, consisting of a movable weighing end, with a fixed twisting end, so as to take different lengths of specimens. The angle of torsion of the specimen and the number of turns to break the specimen are noted in degrees. This test is not applied to rivet material.

ENDURANCE TESTING is done to determine the fatigue of metals. It is made by rotating a specimen under a load approximating the elastic limit in an extreme fiber of the steel, and noting the rotations until crystalization takes place and the specimen breaks. This machine gives data of value for the proportioning and use of special steels in machine design.

IMPACT TESTS are conducted notably on rails and axles, and consists in a Drop Test of a known number of pounds through a given height, thereby imposing a force of a number of foot pounds on a specimen. Small size Impact Testing machines are designed with a pendulum arrangement and are used on nicked specimens. No standards have been adopted for this form of testing other than those applied to rails and axles.

COLD BENDS. Cold bends are made on all rivet stock, and generally on all structural material. They show whether the material is free from seams, whether it is brittle, and whether it will tear on the outside bent portion. Uniformity in conducting these tests should be adopted, and while the Standard Specifications of our Engineering Societies specify Cold Bends, they do not indicate the method of test. A Hydraulic machine should be employed, and which will give a uniformally applied bending load. The practice of making bends under a steam hammer should be discouraged as this is not fair to the test piece. The blows from a sledge also are variable in intensity and do not permit of a flow of the metal. Nicking of test specimens prior to bending cold is a very severe test of condition, and the majority of rivet stock that stands the Cold Bend Flat on itself will likewise stand this test, although the outside fibers have been broken. All rivet material must stand the Cold Bend Test, but it is not required to stand the Nick and Cold Bend Test. In conducting this test the rivet material, and in the case of the finished rivet, the rivet shank must be bent through 180° flat on itself without fracture on the outside of the bent portion.

HOT BENDS, heated and quenched, then bent cold. This test is made to disclose Red Shortness, or whether there are hard spots in the material. If any hardening took place it would destroy the value of the stock as a rivet material. The bends should be made in a Hydraulic machine. Quench test pieces should be heated to a dark cherry red as seen in daylight, and plunged into fresh clean water at from 60° to 90° Farenheit. As a severe test of condition a specimen might be heated, quenched, then nicked and then bent 180° flat on itself. Generally a rivet that stands the quench bend as required through 180° flat on itself, will stand this test.

FLATTENING TEST. A rivet head is flattened hot to a diameter $2\frac{1}{2}$ times the diameter of the rivet shank, and to pass this test must do so without fracture or tears on the edges of the flattened portion. This is done by heating to a full cherry red and flattening with a sledge or under a steam hammer to the required dimension.

COLD FLATTENING TEST. Most rivet stock will flatten to $2\frac{1}{2}$ times the diameter of the rivet shank cold, although this test is not specified.

UPSETTING TEST. Longitudinal specimens shall stand hammering down cold to ½ their original height without showing seams or other defects. A small cylinder approximating 1″ in height is flattened down to a ½ inch cylinder under a steam hammer. In conducting such a test, when the cylinder of steel is on the anvil, it should be turned after each blow to get a uniformally applied load. As such specimens get hot during the test, care should be taken in handling.

The above covers a complete description of the tests usually conducted on material, but all of which are not applied in testing rivets. The following tabulation gives the test to which structural material is usually subjected.

Material.	Tests.
Boiler.	
Plate	Tension, Forging, Punching, Hot and Cold Bends.
Shapes	Tension, Forging, Punching, Welding, Hot and Cold Bends.
Rivets	Tension, Bending, Forging, Cold Bends.
Structural.	
Soft	Tension, Bending, Welding, Hot and Cold Bends.
Medium	Tension, Bending, Welding, Annealing, Hardening.
High	Tension, Bending, Hardening.
Ship.	
Plates	Tension, Punching, Hot and Cold Bends.
Shapes	Tension, Forging, Punching, Welding, Hot and Cold Bends.
Rivets	Tension, Forging, Flattening, Hot and Cold Bends.

MODULUS OF ELASTICITY. When material stretches before rupture and up to the Elastic Limit, the ratio of Total Stretch to Total Stress remains nearly constant. Thus each equal addition of stress produces an equal additional stretch. The Modulus of Elasticity for steel is stress per unit of length ÷ stretch per unit of length, and which is found to be practically a figure of 30,000,000 for most steels.

The following is a tabulation of the general properties of steel as met with in structural work.

PROPERTIES OF STEEL

Kind	Carbon	Tensile Strength	Elastic Limit	Compression Strength	Shearing Strength	Modulus of Elasticity
Soft..........	.10	55000.	30000.	60000.	48000.	29,000,000.
Medium.......	.30	65000.	35000.	65000.	50000.	29,500,000.
Hard.........	.60	80000.	50000.	75000.	65000.	30,000,000.

The composition of our Rivet steel has been averaged for a large number of determinations. These results are representative of the material used during the preceding year, and of the material being used at this time.

CHEMICAL ANALYSIS

Carbon....................	.099
Manganese................	.392
Sulphur....................	.037
Phosphorous................	.0109

PHYSICAL TESTS

Tensile Strength...........	Pounds per square inch..	50784
Elastic Limit..............	Pounds per square inch..	30692
Elongation in 8″...........	Percent...............	32.2
Reduction of Area.........	Percent...............	62.3
Fracture..................................		½ Cup.
Nature of Fracture..........................		Silky.
Shearing Strength.........	Single, pounds per sq. in.	45000
Shearing Strength.........	Double, pounds per sq.in.	91000
Cold Bend................	180° Flat on itself......	OK without fracture
Quench Bend.............	180° Flat on itself......	Without fracture.
Quenched and Nicked......	180° Flat on itself......	Without fracture.
Flattening Test............	To 2½ diameters of shank.	Without tears.

High Tensile Rivets, Double Shear, pounds per square inch, 124900
High Tensile Rivets, Single Shear, pounds per square inch, 64250

The S. Severance Manufacturing Company make rivets to conform to the various standard specifications of the Asociati ns, Societies, Inspection Bureaus, or of the individual.

CHAPTER IV

STANDARD SPECIFICATIONS

Commencing about 1912 a comprehensive effort was made by the various users of material to establish standard specifications. The American Society for Testing Materials was largely responsible for the undertaking, which originally presented many difficulties. The Association of American Steel Manufacturers probably started the campaign for uniformity of specification, and the Steel Manufacturers early benefitted by the standards adopted. Although there is close agreement among the specifications for steel now recognized as standard, there are many standards, and probably the next few years will see some eliminated and the approach to still more uniformity. The Government of the United States as represented in its various construction departments does not adopt the standards as established by the various Associations, and governmental specifications often show a marked departure in many respects from commercial standards. Future standardization would indicate the desirability of the Government Departments, such as the Navy, specifying material to the standardized specifications established.

On page 25 there is a Tabulation showing various standard requirements for Rivet Bars and Manufactured Rivets, which will indicate the agreement and peculiarities of the several specifications. For more complete understanding of Rivet Specifications, the Boiler Code Requirements of the American Society of Mechanical Engineers is quoted as far as rivets is concerned. The Standard Specification of the American Society for Testing Materials is quoted in toto, and the requirements of the Navy Department, Bureau of Construction and Repair, for Boiler Rivets are quoted. In chapters to follow much information is given in relation to other standards and other requirements.

STANDARD SPECIFICATIONS FOR RIVET ROD AND RIVETS

Standard of............	Boiler Code A.S.M.E.	A.A.S.M.	A.S.T.M.	A.S.T.M.	A.S.T.M.	A.R.E.A.	A.S.T.M.	A.S.T.M.
For Rivets for..........	Boiler	Boiler	Boiler	Structural	Structural Nickel	Bridge	Bridge	Ship
Chemical Analysis.								
C................	....	....	....	....	not over .30	....	....	....
Mn...............	.30 to .50	.30 to .50	.30 to .50	....	" .60	....	....	....
P, Acid, not over..	....	.040	....	....	" .040	.040	.040	.060
P, Basic, not over..	.040	.040	.040	.060	" .030	.040	.040	.040
S, not over..	.045	.045	.045	.045	" .045	.040	.045	.045
Nickel............	....	....	....	....	over 3.25	....	....	....
Physical Tests.								
Tensile strength....	45000—55000	45000—55000	45000—55000	46000—56000	70000—80000	50000	46000—56000	55000—65000
Yield point, over...	½ Tensile	½ Tensile	½ Tensile	½ Tensile	min. 45000	25000	½ TS.	½ Tensile
Elongation in 8″ % min..	1500000 ÷ TS	1450000 ÷ TS	1500000 ÷ TS not exc'd 30%	1400000 ÷ TS	1500000 ÷ TS	1500000 ÷ TS	1500000 ÷ TS	1500000 ÷ TS
Reduction Area % min..	....	....	....	....	min. 40%	....	....	....
Bends:—								
Cold Bend.........	180° Flat	180° Flat	180° Flat	180° Flat	180° Flat	180° Flat	180° Flat	180° Flat
Quench Bends......	180° Flat	180° Flat	180° Flat	....	....	Nick Bend(*)	....	....
Number of test per melt.								
Tension...........	2	2	2	1	1	....	1	2
Cold Bend.........	2	2	2	1	1	....	1	2
Quench Bend.......	2	2	2	....	....	....	....	....
Tests on Manufactured Rivets.								
Rivet Shank Bend, Cold.	180° Flat	....	180° Flat	....	....	....	....	180° Flat
Flattening of Rivet Head Hot to............	2½ dia. of Rivet Shank	....	2½ dia. of Rivet Shank	....	....	....	....	2½ dia. of Rivet Shank
Number of tests for each lot of Rivets.								
Shank Bends.......	3	....	3	....	....	....	....	3
Flattening tests.....	3	....	3	....	....	....	....	3

NOTE:—A.S.M.E. = American Society of Mechanical Engineers.
A.A.S.M. = Association of American Steel Manufacturers.
A.S.T.M. = American Society for Testing Materials.
A.R.E.A. = American Railway Engineering Association.

(*). The Nick bend specified is made by nicking the Rivet Bar and then bending cold around a diameter equal to the rivet shank. The tear must be of a silky nature and gradual.

Quench bends are made by heating the test specimens to a dark cherry red as seen in daylight and immersing in clean water at 80° to 90° Farenheit. Other tests have been described in detail in Section 2.

SPECIFICATIONS FOR BOILER RIVET STEEL OF THE A.S.M.E.

A. REQUIREMENTS FOR ROLLED BARS

I. Manufacture

PROCESS. The Steel shall be made by the Open Hearth Process.

II. Chemical Properties and Tests

CHEMICAL COMPOSITION. The steel shall conform to the following requirements as to chemical composition.

Manganese.................................0.30—0.50 %
Phosphorous..............................not over 0.04 %
Sulphur......................................not over 0.045%

LADLE ANALYSIS. An analysis to determine the percentages of carbon, manganese, phosphorous, and sulphur shall be made by the manufacturer from a test ingot taken during the pouring of each melt, a copy of which shall be given to the purchaser or his representative. This analysis shall conform to the requirements given under CHEMICAL COMPOSITION.

CHECK ANALYSIS. Analyses may be made by the purchaser from finished bars, representing each melt, which shall conform to the requirements specified in CHEMICAL COMPOSITION.

III. Physical Properties and Tests

TENSION TESTS. (a). The bars shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in...................45000—55000
Yield point, min., lb. per sq. in..................0.5 Tens. Str.
Elongation in 8″, min., per cent...1,500,000 ÷ Tens. Str. but need not exceed 30%

(b). The yield point shall be determined by the drop of the beam of the testing machine.

BEND TESTS. (a). COLD BEND TESTS. The specimen shall bend cold through 180° flat on itself without fracture or cracking on the outside of the bent portion.

(b). QUENCH BEND TESTS. The test specimen, when heated to a light cherry red as seen in the dark (not less than 1200° Farenheit), and quenched at once in water the temperature of which is between 80° and 90° Farenheit, shall bend through 180° flat on itself without cracking on the outside of the bent portion.

TEST SPECIMENS. Tension and Bend test specimens shall be of the full size section of the bars as rolled.

NUMBER OF TESTS. (a). Two tension, two cold bend, and two quench bend tests shall be made from each melt, each of which shall conform to the requirements specified.

(b). If any test specimen develops flaws, it may be discarded and another specimen substituted.

(c). If the percentage of elongation of any tension test specimen is less than that specified, and any part of the fracture is outside the middle third of the gaged length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN GAGE. The gage of each bar shall not vary more than 0.01 inch from that specified.

WORKMANSHIP AND FINISH

WORKMANSHIP. The finished bars shall be circular within 0.01 inch.

FINISH. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

MARKING. Rivet bars shall, when loaded for shipment, be properly separated and marked with the name of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

INSPECTION AND REJECTION

INSPECTION. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to the shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

REJECTION. (a). Unless otherwise specified, any rejection based on tests made in accordance with Check Analyses shall be reported within five working days from the receipt of samples.

(b). Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

REHEARING. Samples tested in accordance with Check Analyses which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B. REQUIREMENTS FOR RIVETS

I. Physical Properties and Tests

TENSION TESTS. The rivets, when tested, shall conform to the requirements as to tensile properties specified for Rivet Bars, except that the elongation shall be measured on a gaged length not less than four times the diameter of the rivet.

BEND TESTS. The rivet shank shall bend cold through 180° flat on itself as shown in Figure 1., without cracking on the outside of the bent portion.

FLATTENING TESTS. The rivet head shall flatten, while hot, to a diameter 2½ times the diameter of the shank, as shown in Figure 2, without cracking at the edges.

NUMBER OF TESTS. (a). When specified, one tension test shall be made from each lot of rivets offered for inspection. (b). Three bend and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

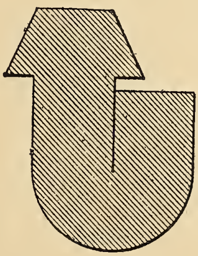


FIG. 1
The Bend Test
for Rivets

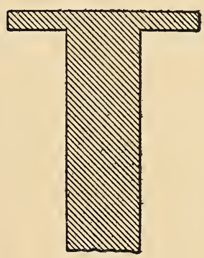


FIG. 2
The Flattening
Test for Rivets

II. Workmanship and Finish

WORKMANSHIP. The rivets shall be true to form, concentric, and shall be made in a workmanlike manner.

FINISH. The finished rivets shall be free from injurious defects.

III. Inspection and Rejection

INSPECTION. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concerns the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

REJECTION. Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS FOR RIVET STEEL FOR SHIPS.
A 13-14.

AMERICAN SOCIETY FOR TESTING MATERIALS.

A. REQUIREMENTS FOR ROLLED BARS

I—Manufacture

PROCESS. 1. The steel shall be made by the open hearth process.

II—Chemical Properties and Tests

CHEMICAL COMPOSITION. 2. The steel shall conform to the following requirements as to chemical composition:

Phosphorous	Acid	not over 0.060 per cent.
	Basic	nor over 0.040 per cent.
Sulphur		not over 0.045 per cent.

LADLE ANALYSIS. 3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentage of carbon, manganese, phosphorous and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

CHECK ANALYSIS. 4. Analyses may be made by the purchaser from finished bars representing each melt. The phosphorous and sulphur contents thus determined shall not exceed that specified in Section 2 by more than 25 per cent.

III—Physical Properties and Tests

TENSION TESTS. 5. (a). The bars shall conform to the following requirements as to tensile properties:

Tensile Strength, lbs. per sq. in.	55000 — 65000.
Yield Point, min., lbs. per sq. in.	0.5 Tens. Str.
Elongation in 8″, min. per cent	1500000 ÷ Tens. Str.

(b). The yield point shall be determined by the drop in the beam of the testing machine.

MODIFICATION OF ELONGATION. 6. For bars over $\frac{3}{4}$ inch in diameter, a deduction of one from the percentage of elongation specified in Section 5 (a), shall be made for each increase of $\frac{1}{8}$ inch in diameter above $\frac{3}{4}$ inch.

BEND TESTS. 7. The test specimen shall bend cold through 180° flat on itself without cracking on the outside of the bent portion.

TEST SPECIMENS. 8. Tension and bend test specimens shall be of the full-size section of bars as rolled.

NUMBER OF TESTS. 9. (a). Two tension and two bend tests shall be made from each melt, each of which shall conform to the requirements specified; except that if bars from one melt differ $\frac{3}{8}$″ or more in di-

ameter, one tension and one bend test shall be made from both the greatest and the least diameters rolled.

(b). If any test specimen developes flaws, it may be discarded and another specimen substituted.

(c). If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (a), and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV—Permissible Variations in Diameter

PERMISSIBLE VARIATIONS. 10. The diameter of bars one inch or under in diameter shall not vary more than 0.01 inch from that specified; the diameter of bars over one inch to and including two inches in diameter shall not vary more than 1/64 inch under nor more than 1/32 inch over that specified.

V—Finish

FINISH. 11. The finished bars shall be free from injurious defects, and shall have a workmanlike finish.

VI—Marking

MARKING. 12. Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

VII—Inspection and Rejection

INSPECTION. 13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall furnish the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

REJECTION. 14. (a). Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples.
(b). Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer so notified.

REHEARINGS. 15. Samples tested in accordance with Section 4, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B. REQUIREMENTS FOR RIVETS

VIII—Physical Properties and Tests

TEST CERTIFICATE OF ROLLED BAR.

16. A copy of the results of tension tests of the rolled bars from which the rivets were made shall be furnished for each lot of rivets.

TENSION TESTS.

17. If the test certificate required in Section 16 cannot be furnished the rivets shall conform to the requirements as to tensile properties specified in Sections 5 and 6, except that the elongation shall be measured on a gage length as great as the length of the rivets tested will permit.

BEND TESTS.

18. The rivet shank shall bend cold through 180° flat on itself as shown in Figure 1, without cracking on the outside of the bent portion.

FLATTENING TESTS.

19. The rivet head shall flatten, while hot, to a diameter $2\frac{1}{2}$ times the diameter of the shank, as shown in Figure 2, without cracking at the edges.

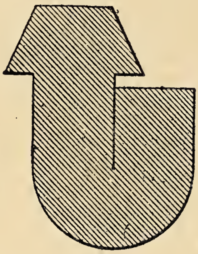


FIG. 1

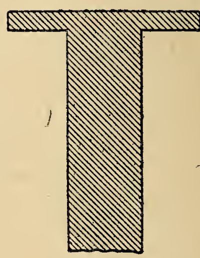


FIG. 2

NUMBER OF TESTS.

20. (a). When required in accordance with Section 17, one tension test shall be made from each size in each lot of rivets offered for inspection.

(b). Three bend and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

IX—Workmanship and Finish

WORKMANSHIP.

21. The rivets shall be true to form, concentric, and shall be made in a workmanlike manner.

FINISH.

22. The finished rivets shall be free from injurious defects.

X—Inspection and Rejection

INSPECTION.

23. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

REJECTION.

24. Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

NAVY DEPARTMENT SPECIFICATION 43R3.
BOILER RIVETS

General Instructions.

1. General Specifications for the Inspection of Material, issued by the Navy Department, in effect at date of opening of bids, shall form part of these specifications.

RODS FOR BOILER RIVETS

Chemical and Physical Requirements.

2. The physical and chemical characteristics of rods for rivets are to be in accordance with the following table.

Class	A.	B.	C.
Material	Open Hearth Nickel or Carbon Steel	Open Hearth Carbon Steel	Commercial Steel
Minimum Tensile Strength. Lbs. per sq. in............	75000.	58000.	....
Minimum Elongation in 8″ %..........	23.	28.	....
Sulphur. Max....... Phosphorous Max...	0.035 0.040	0.035 0.040	....
Cold Bend..........	180° about an inner diameter equal to ½ the thickness of the test piece for diameters up to and including 1″, and equal the thickness for diameters over 1″....	Flat back through 180°	....
Quench Bend.......	180° about an inner diameter equal to the thickness of the test piece for diameters up to and including 1″, and equal to 1½ times the thickness for diameters over 1″.	180° through an inner diameter equal to ½ the thickness of the test piece for diameters up to and including 1″, and equal to the thickness for diameters over 1″.	....

In connection with the table. Elongation for rounds ½ inch and less in diameter shall be measured in an original length equal to 16 times the diameter of the test piece; for material over ½ inch up to and including 1 inch in diameter, the elongation shall be measured in a length of 8 inch; and for material over 1 inch in diameter up to and including 2 inch in diameter, the required percentage of elongation measured in a length of 8 inches, shall be reduced by 1 for each increase in diameter of ¼ inch or fraction thereof above 1 inch.

Quench bends test pieces to be heated to a dark cherry red, as seen in daylight, and plunged into fresh clean water of 80° to 90° Farenheit.

PLACE OF INSPECTION OF RODS.

3. If the contractor desires, and so states on his orders, or if inspection at the place of manufacture of the rods is considered impracticable to the bureau concerned, the bureau will direct that the inspection of the rods be made at the place of manufacture of the rivets instead of at the place where the rods are rolled.

SURFACE AND OTHER DEFECTS.

4. The rods must be true to form, free from seams, hard spots, brittleness, injurious sand or scale marks, and injurious defects generally.

TENSILE TEST.

5. One tensile test piece shall be taken from each ton or fraction thereof of rods rolled from the same heat. If, however, the rods in one heat are not of the same diameter, then the inspector will take such additional test pieces as he may consider necessary according to the number of different sizes of rods in the heat. When practicable, but one test piece will be cut from each rod selected for the test. Should any test piece be found too large in diameter for the testing machine, the piece may be prepared for test in the manner prescribed for forgings.

BENDING TESTS.

6. If the total weight of the rods rolled from the same heat amounts to 6 tons or more, four cold bending tests and four quench bending test pieces will be taken; but if the weight is less than 6 tons, one half that number of test pieces will suffice.

UPSETTING TESTS.

7. From each heat of rounds as rolled there shall be cut 6 test specimens about $1\frac{1}{2}$ inches long, which shall be hammered down cold, longitudinally, to half their original length without showing seams or other defects which would tend to produce imperfections in the finished product.

COMPLETED BOILER RIVETS

DESCRIPTION.

8. Rivets must be true to form, concentric, and free from injurious scale, fins, seams, and all other injurious defects. If the material is found to be very uniform and none of the tests made of a series of lots fail, the inspector may discontinue the tests after he has made enough to satisfy himself that the whole of the material on the order is satisfactory.

TESTS.

9. Samples from each lot must stand the following tests without fracture, test (a) being applied to one lot and (b) to a second, etc.

(a). Bend double cold to a curve of which the inner diameter is equal to the diameter of the rivet.

(b). Bend double hot through an angle of 180° flat back.

(c). The head to be flattened when hot without cracking at the edges until its diameter is $2\frac{1}{2}$ times the diameter of the shank.

(d). The shanks of sample rivets to be nicked on one side and bent cold to show the quality of the material.

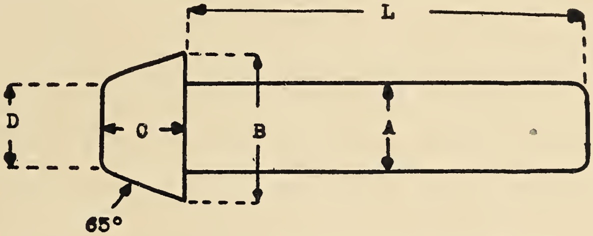
PURPOSE.

10. Class A material to be used for all rivets where Class A plate is used.

Class B material to be used with Class B boiler plate.

Class C material shall be used for rivets where the strength of the boiler is not affected.

NOTE.—It is preferred that rivets conform in general to the dimensions shown on the following table. Nonessential deviations from the dimensions shown will, however, be permitted.

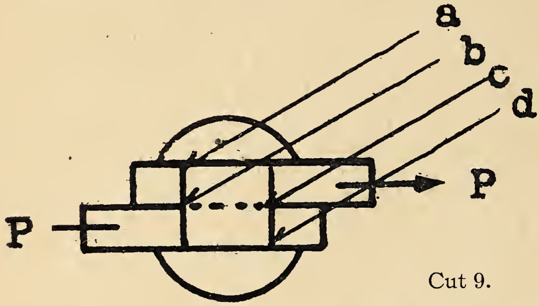


A.	B.	C.	D.	Weight of 10 heads	Weight per inch of Shank L
				pounds	pounds
1/2	15/16	7/16	1/2	0.531	0.0556
9/16	1	1/2	9/16	.713	.0704
5/8	1 1/8	9/16	5/8	1.007	.0869
11/16	1 1/4	5/8	11/16	1.372	.1052
3/4	1 5/16	5/8	3/4	1.551	.1251
13/16	1 7/16	11/16	13/16	2.033	.1470
7/8	1 1/2	11/16	7/8	2.258	.1703
15/16	1 5/8	3/4	15/16	2.871	.1956
1	1 3/4	13/16	1	3.584	.2225
1 1/16	1 13/16	13/16	1 1/16	3.910	.2512
1 1/8	1 15/16	7/8	1 1/8	4.761	.2816
1 3/16	2	7/8	1 3/16	5.170	.3137
1 1/4	2 1/8	15/16	1 1/4	6.215	.3477
1 5/16	2 1/4	1	1 5/16	7.391	.3833
1 3/8	2 3/8	1 1/16	1 3/8	8.490	.4207
1 7/16	2 1/2	1 1/8	1 7/16	9.941	.4599
1 1/2	2 5/8	1 3/16	1 1/2	11.507	.5006
1 9/16	2 3/4	1 1/4	1 9/16	13.242	.5433
1 5/8	2 7/8	1 5/16	1 5/8	15.146	.5876
1 11/16	3	1 3/8	1 11/16	17.300	.6336
1 3/4	3 1/8	1 7/16	1 3/4	19.485	.6815

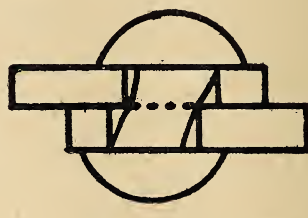
In the foregoing standard specifications it will be noted that reduction of area measurements are seldom specified. The value of reduction of area as a measurement has been questioned. As an example of the stand taken in relation to this measurement it might be stated that the executive committee of the Board of Supervising Inspectors of the U. S. Steamboat Inspection Service adopted a rule eliminating the reduction of area from steel boiler plate specifications, pending an investigation of the U. S. Bureau of Standards in 1916. Their stand was approved by the Secretary of Commerce.

CHAPTER V
RIVETED JOINTS

A rivet connecting two plates is almost always in shear. The shearing forces do not act in the plane of the section BC, as shown in Cut 9, but along the centers of the connecting plates. Due to the friction and the rigidity of the edges of the plates the point of application of the shearing force "P," on the surface of the rivet may be practically the line BC. If the rivet fits the rivet hole loosely, the rivet bends and the force distribution is unequal. This is illustrated in Cut 10. It is usual to assume that rivets fit their holes tightly, and that the Shearing Force acting on the rivet, is the force tending to shear divided by the Cross Sectional area of the rivet.

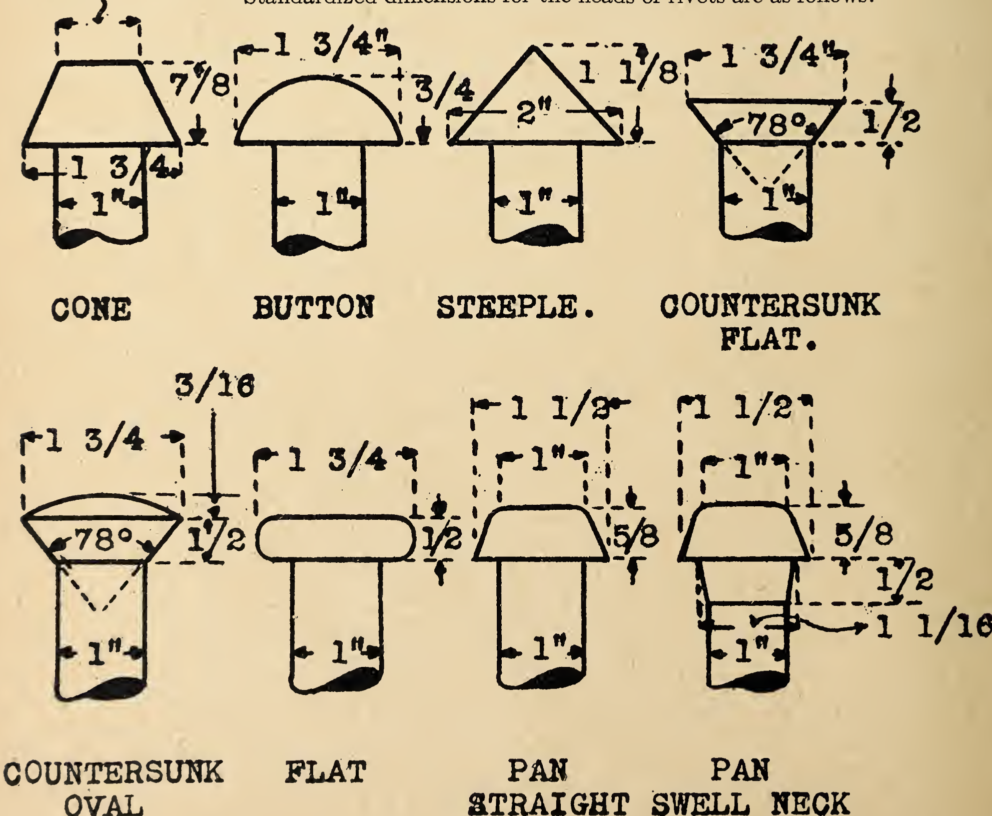


Cut 9.


Cut 10.

STANDARD HEADS

Standardized dimensions for the heads of rivets are as follows:



Cut 11.

PROPORTIONS OF STANDARD HEADS

Cone Head.

Least diameter, 15/16 times the diameter of the rivet shank.
Greatest diameter, 1¾ times the diameter of the rivet shank.
Height, ⅞ times the diameter of the rivet shank.

Button Head.

Diameter, 1¾ times the diameter of the rivet shank.
Height, ¾ times the diameter of the rivet shank.

Steeple Head.

Diameter, 2 times the diameter of the rivet shank.
Height equal to 1⅛ times the diameter of the rivet shank.

Countersunk Flat Head.

Height, ½ times the diameter of the rivet shank.
Taper 78°.

Countersunk Oval Head.

Greatest diameter, 1¾ times the diameter of the rivet shank.
Taper 78°.
Height of countersink, ½ times the diameter of the rivet shank.
Height of oval, 3/16 times the diameter of the rivet shank
Radius of Oval, 2¼ times the diameter of the rivet shank.

Flat Head.

Diameter, 1¾ times the diameter of the rivet shank.
Height, ½ times the diameter of the rivet shank.

Pan Head.

Greatest diameter, 1½ times the diameter of the rivet shank.
Least diameter, equal to the diameter of the rivet shank.
Height, ⅝ times the diameter of the rivet shank.

Pan Head Swell Neck.

Same as for the Pan Head, except:
Necking in, ½ times the diameter of the rivet shank.
Swelled out to 1/16″ plus the diameter of the rivet shank, for the diameter just under the rivet head.

When a rivet is driven at a full heat, the contraction of the rivet on cooling nips the connected plates powerfully, and if the rivet is long causes a considerable tensional force in the cooled rivet. This contraction also causes a frictional resistance against slipping between the connected plates. An estimated figure for the amount of tension so existing in a driven rivet is 20,000 pounds per square inch of cross section of the rivet, and the friction due to the nipping of the plates as approximately 7000 pounds per inch of rivet section. It is customary, however, to ignore these figures, in the design of joints. This is the proper procedure as in service, due to strains, vibrations, and other forces, there is a tendency to slightly elongate the rivet, and this may cause the frictional resistance to ultimately become zero.

LENGTH OF RIVETS

Generally speaking a rivet should never be longer than six (6) times its diameter. Although rivets are made for special purposes, 12 inches or more in length, such rivets when driven must be cooled in the center prior to driving, otherwise the contraction on cooling would split off the heads. Bridge and other specifications strictly limit the length of rivets.

AMOUNT OF MATERIAL IN A FORMED HEAD COMPARED TO STEEL IN THE SHANK

In forming a head an allowance of 1.6 times the diameter of the shank is customary in Button Head Rivets.

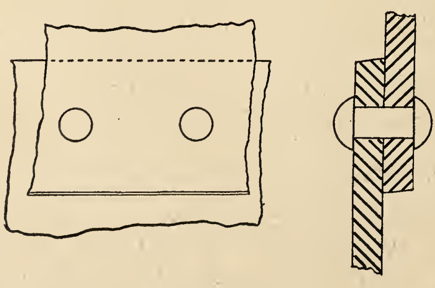
For Countersunk Rivets this allowance amounts to $\frac{3}{4}$ times the diameter of the shank.

RIVETED JOINTS

Whether used for boiler, structural, or for ship construction the types of riveted joints possible to use are limited. There are two general types of joints.

Lap Joint

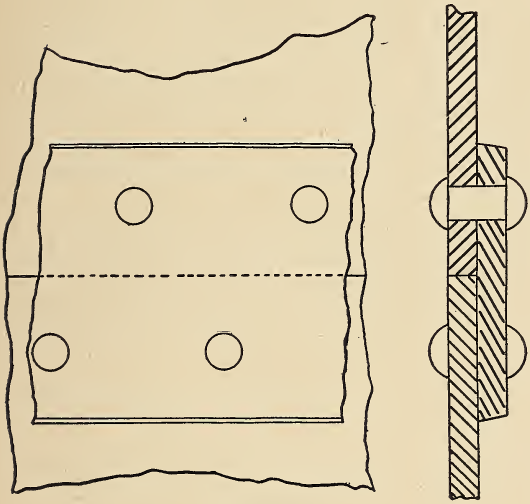
When one plate is made to overlap the other, and one or more rows of rivets are put through the two plates, the riveting is called Lap Riveting, and the joint a Lap Joint. This is illustrated in Cut 12.



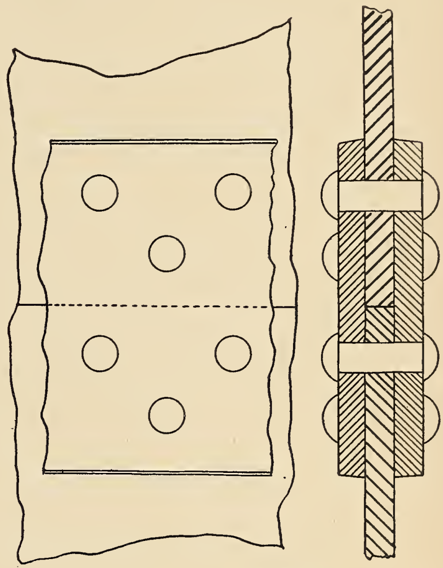
Cut 12.

Butt Joint

When the plates are butted together at their edges, and are covered by a cover plate or Butt Strap through which the rivets pass, the riveting is Butt Riveting, and the joint called a Butt Joint. There may be used but a single cover plate, or there may be two cover plates, one in front and the other in back of the joint. Cut 13 illustrates a Butt Joint with a single cover plate or strap, while Cut 14 illustrates a Butt Joint with cover plates front and back, or a double butt strap.

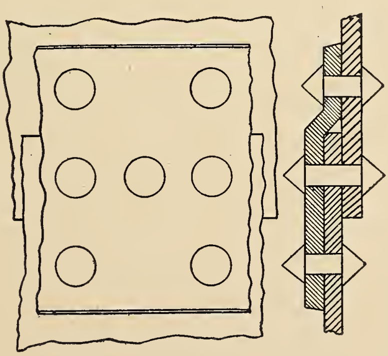


Cut 13.



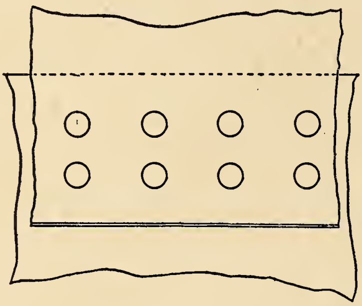
Cut 14.

In addition to these two general types of joints, there is also a combination of the two, called a Combination Lap and Butt Joint. It consists of a Lap Joint with a cover plate outside the joint. In this case three rows of rivets are required, and it is customary to have twice the number of rivets in the middle row as in the outside rows. This joint is illustrated in Cut 15.

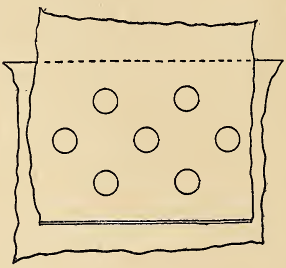


Cut 15.

Joints are further divided according to the number of rows of rivets that they contain, into Single, Double, or Triple Riveted Joints. The rivets are usually staggered in arrangement, although in structural work the chain arrangement is often used. Cut 16 illustrates Chain Riveting, while Cut 17 shows a Triple Riveted Lap Joint, with the rivets Staggered in arrangement. In Butt Joints the arrangement of the rivets is duplicated on each side of the joint, and the style of riveting is named according to the arrangement on one side.



Cut 16.

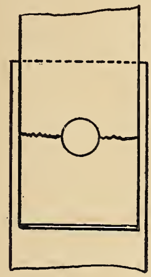


Cut 17.

The correct design of riveted joints is highly important, and while there are numerous rules as compiled by different authorities, the fundamental object in design of riveted joints is the obtaining of adequate strength with the economical use of material. Before proceeding with the proportioning of joints, it is well to consider the manner in which a joint will fail. Failure around any one rivet is exemplifying of general failure, as follows:

Simple Single Riveted Lap Joint:—Subject to tension each rivet is supporting a strip of plate equal in width to the distance between the rivets. This distance between rivets, from center to center, is called the pitch. Fracture or failure of this joint may occur in four ways.

1. The plate may tear across, as illustrated in Cut 18 A. The smallest area of the plate is through the rivet hole, and is equal to the pitch in inches minus the diameter of the rivet hole in inches. The resistance to tension is the force of tension acting, times this net area, times the thickness of the plate. This might be expressed:

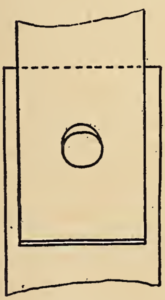


Cut 18A.

$$Ft = (P - d) \times t.$$

Where
F_t = Tensile Strength of Plate Material.
P = Pitch of the Rivets in inches.
d = Diameter of the Rivet Hole in inches.
t = Thickness of the Plate in inches.

2. The plate and the rivet may be crushed, as illustrated in Cut 18 B. This crushing would cause the rivet to become loose in its hole, and the whole joint insecure on that account. The bearing area on which the crushing force acts is the diameter of the rivet hole times the thickness of the plate. The resistance to crushing is the resistance of the plate or rivet material to crushing, times the diameter of the rivet hole, times the thickness of the plate. This might be expressed:

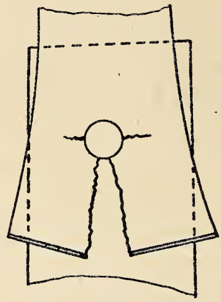


Cut 18B.

$$Fc = (P - d) \times t = \text{Resistance to Crushing.}$$

Where
F_c = Crushing Strength of the Material.
P = Pitch of Rivets in inches.
d = Diameter of the Rivet Hole in inches.
t = Thickness of the Plate in inches.

3. The plate may break across in front of the rivet, as illustrated in Cut 18 C, this action being similar to a Transverse break in a beam supported at the ends and loaded in the middle. The bending moment is $\frac{1}{8}$ T d. The failure of a joint by this tearing out of the plate in front of the rivet can be safely guarded against by making the row of rivets at the proper distance from the edge of the plate. By experiments and experience this has been found to be about 1 diameter of the rivet from the edge of the rivet hole, or $1\frac{1}{2}$ diameters from the center of the rivet hole to the edge of the plate. Minimum spacing from the edge of plates is embodied in all specifications.



Cut 18 C.

4. The rivet may shear across as illustrated in Cut 18 D. The area resisting shear is .7854 d^2, and the resistance to shearing is thus as follows:

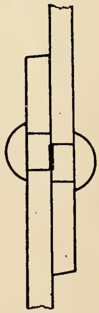
$$\text{Resistance to Shear} = F_s \times .7854\, d^2.$$

Where:

F_s = Unit Resistance to Shear of the Rivet Material.

d = Diameter of the Rivet Hole in inches.

In the illustration the rivet is in single shear. Were this a Butt Joint with the rivet going through two cover plates, the rivet would be in double shear, and thus presenting twice the area resisting shear. It is customary to take double the value of single shear resistance for double shear, although some Bureaus such as the British Board of Trade, allow but $1\frac{3}{4}$ times the value of single shear resistance for double shear.



Cut 18 D.

The strength of riveted joints is determined by whichever is the weaker of the two, the plate or the rivets. It is practice to design the joint so that the strength of the plate and the rivets are equal. In boiler work on account of the possibility of corrosion of the plates, and hence loss in strength in use, it is considered good practice to give the plates a slight, excess in strength over the rivets. Joints are compared after design with the strength of the plate unpunched, this comparison being known as the Efficiency of Joints.

The series of possible joints is considered in the following, and which is in accordance with good practice. In order to illustrate the usage of factors the methods of the British Board of Trade is used. In these calculations the following symbols are used.

P. = Pitch, distance from center to center of rivets in the same row in inches. Where there is different spacing in different rows of rivets the larger spacing is the Pitch.

d. = Diameter of the Rivet Hole, or of the Rivet after driving, in inches.

t. = Thickness of the Plate material in inches.

UT. = Ultimate Tensile Strength of the Plate Material in pounds per square inch.

US. = Ultimate Shearing Strength of the Rivet Material in pounds per square inch. This being value for single shear.

UC. = Ultimate Crushing Strength of the Plate material in pounds per square inch. Valued at 95,000 lbs.

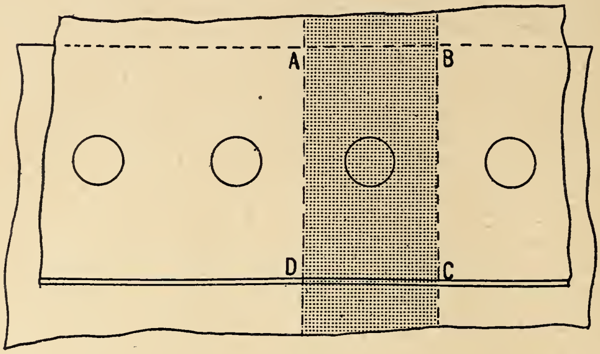
X. = Diagonal Pitch, in inches.

Y. = Horizontal Distance between rows.

The Efficiency of a Joint is the ratio of the strength of the Riveted Joint, compared to a strip of plate material in width equal to the pitch used, and NOT punched for the rivet holes.

JOINT I

SINGLE RIVETED LAP JOINT



Cut 19.

The element on which strength is figured is ABCD, colored for identification. This element contains one rivet, and its width is P, the pitch.

Strength of the Plate $= t \times (P - d) \times UT$.

Strength of the Rivet $= .7854\ d^2 \times US$.

Crushing Strength of Plate in Front of one rivet $= d \times t \times UC$.

By standardized proportioning of size of rivet to thickness of plate, calculation of crushing strength becomes unnecessary. A general rule for this type of joint is that the diameter of the rivet should not be less than 1.5 times the thickness "t," and not over 2.5 times the thickness "t." The lower value is used on very thick plates, and in order to guard against crushing of the plates the upper value 2.5 should not be exceeded.

For equal strength of plate and rivets, the two equations for strength should be formulated thus:

$$t \times (P - d) \times UT = .7854\ d^2 \times US.$$

The tensile strength of the plate UT may be taken as 60000 lbs.
The shearing strength of the rivets US may be taken as 45000 lbs.

Thus $tP - td = .7854\ d^2 \times 45000 \div 60000$.

or $P/d - 1 = .7854 \times .75 \times d/t$

then $P/d = 1 + .59\ d/t$

$P = d\ (1 + .59\ d/t)$

If we take 2 as the ratio between diameter of the rivet and the thickness of the plate, we get:

$P = d\ (1 + .59 \times 2)$

$P = 2.18\ d$.

That is for equal strength of plate and rivets the pitch should be 2.18 times the diameter of the rivet.

In designing such a joint, it naturally follows that conventional sizes of rivets and common thickness of plates, and the pitch distance would be governed by fractions of an inch and not the decimal parts thereof. Thus to figure this joint practically proceed as follows:

1. Select a rivet according to the thickness of the plate.

2. Take the ratio of the British Board of Trade for tensile strength of the plate versus the shearing strength of the rivet material as .821. In our previous calculation we took .75 as this ratio using 60000 lbs. for the plate and 45000 lbs. for the rivet. Doing so our formulae for pitch becomes

   $$P = d\,(1 + .645\ d/t).$$

   Calculate this pitch.

3. Select the nearest working dimension for the pitch as figured in "2," taking the next highest $\frac{1}{8}''$, which gives the plate a slight advantage in strength.

4. Find the strength of the plate, subtract the diameter of the rivet from the pitch, multiply by the thickness "t," of the plate, and then by the tensile strength of the plate material in pounds per square inch.

5. Find the strength of the rivets, by multiplying the cross section area of the rivet, vis., .7854 d^2, by the factor .821 and then by the tensile strength of the plate material in pounds per square inch.

6. Find the strength of the original plate without the rivet hole therein by multiplying the pitch by the thickness of the plate, and then by the tensile strength of the plate material in pounds per square inch.

7. Find the efficiency of the joint by taking the lower value as found in either 4 or 5 and dividing by the results in 6.

NOTE:—Common practice demands the stamping of the tensile strength on plates, whereas the actual tensile strength of the rivets that will be used is unknown. Thus the factor .821 is a safe way for calculation.

In no case should the pitch exceed 10 inches. For boiler work take a value for this joint as follows:

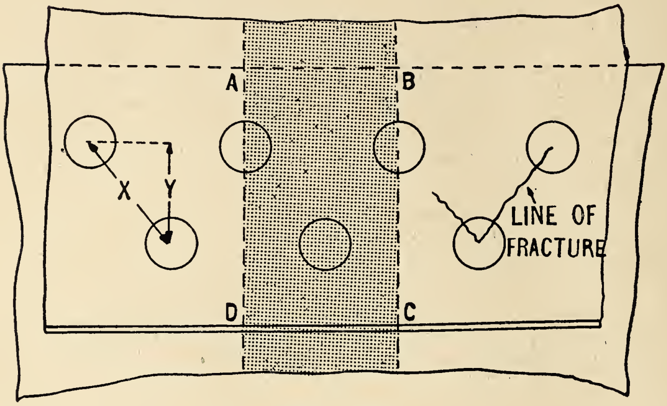
$$P = 1{:}31\ t + 1\tfrac{5}{8}''$$

The distance from the center line of the rivets to the edge of the plate should not be less than $1\frac{1}{2}$ d.

JOINT 2

DOUBLE RIVETED LAP JOINT

Rivets Staggered



Cut 20.

The element on which strength is figured is ABCD colored for identification. This element contains one whole rivet and two half rivets, a total of two rivets.

Danger from rupture along a Zig Zag line as illustrated on a line between the rivet holes is avoided, by having the DIAGONAL PITCH, denoted by "X," sufficiently great. Experimentation has demonstrated that the minimum distance allowable, and although greater values may be used, it should never be less than:

$$X = (.6\,P + .4\,d).$$

With this limiting factor in hand, the horizontal distance between rows becomes a limited value, and the distance in this joint, between the two rows of rivets, accordingly should not be less than:

$$Y = \sqrt{(1.1\,P + .4\,d)\,(.1\,P + .4\,d)}.$$

Figuring as for Joint 1, with above limitations, we get:

$$\text{Strength of Plate} = t\,(P - d) \times UT.$$

$$\text{Strength of Rivets} = 2 \times .7854\,d^2 \times US.$$

For equal strength of Plate and Rivets, we get:

$$t\,(P - d) \times UT = 1.5708\,d^2 \times US.$$

If we take our former ratio of .821 for US/UT we get:

$$P = d\,(1 + 1.29\,d/t).$$

To calculate this joint, proceed as follows:

1. Select a rivet according to the thickness of the plate.
2. Find the pitch, using the formulae $P = d\,(1 + 1.29\,d/t)$.
3. Find the diagonal pitch, as above.
4. Find the distance between rows, as above.
5. Find the strength of the plate, subtracting the diameter of ONE rivet from the pitch, multiplying by the thickness of the plate, and then by the tensile strength of the plate material in pounds per square inch.

6. Find the strength of the rivets, taking two rivets in single shear, thus multiplying the cross section of one, vis .7854 d^2 by 2, then by .821, and then by the tensile strength of the plate material in pounds per square inch.
7. Find the strength of the original plate without rivet holes by multiplying the pitch by the thickness of the plate, and then by the tensile strength of the plate material in pounds per square inch.
8. Find the efficiency of the joint, by dividing the lowest result, punched plate or the rivets, by the results of 7.

NOTE:—For Boiler work the value of the pitch should not be greater than

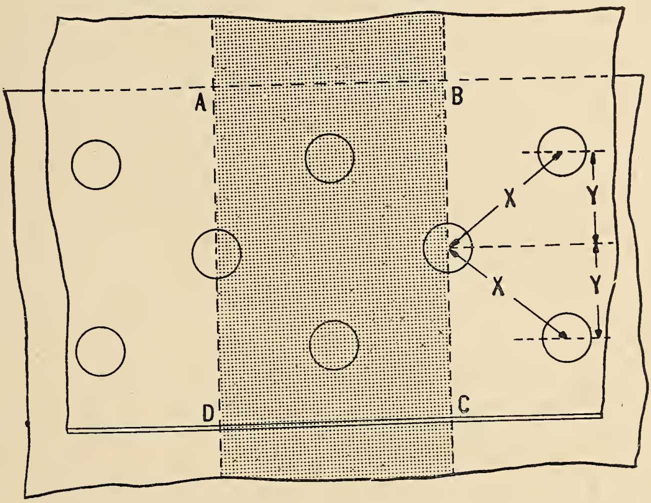
$$P = 2.62\ t + 1\tfrac{5}{8} \text{ inches.}$$

The distance from the center line of the nearest row of rivets to the edge of the plate should not be less than $1\frac{1}{2}$ d.

Thus the total lap of this joint will be $2 \times 1\frac{1}{2}$ d + "Y.", or 3 d + Y. = width of lap.

The diameter of the rivets used may vary from 1.5 t, to 2.5 t, for the same reasons as described in Joint 1.

JOINT 3
TRIPLE RIVETED LAP JOINT



Cut 21.

The element on which strength is figured is ABCD, and colored for identification. This element contains two whole rivets and two half rivets a total of three rivets in single shear.

In this joint the diagonal pitch must be similar to Joint 2, vis:

$$X \text{ not less than } .6\ P + .4\ d.$$

And thus the horizontal distance "Y" between rows becomes:

$$Y \text{ not less than } \sqrt{(1.1\ P + .4\ d)\ (.1\ P + .4\ d)}.$$

Since there are three rows of rivets in this joint, the total lap is

$$3\ d + 2\ Y = \text{Lap.}$$

$$\text{Strength of Plate} = t\ (P - d) \times UT.$$

$$\text{Strength of Rivets} = 3 \times .7854\ d^2 \times US.$$

For equal strength of plate and rivets we get:

$tP - td = 2.3562\ d^2 \times US/UT$, and if we take our former ratio for US/UT,

$$P = d\ (1 + 1.935\ d/t).$$

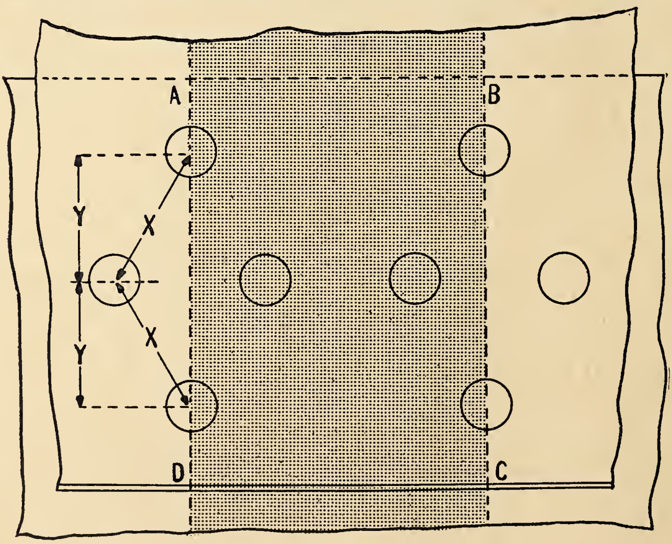
To figure this joint:

1. Select a rivet according to the thickness of the plate.
2. Find the pitch using the above formula.
3. Find the diagonal pitch as above.
4. Find the distance between rows as above.
5. Find the strength of the plate, subtracting the diameter of ONE rivet, multiplying by the thickness, and then by the tensile strength of the plate material in pounds per square inch.
6. Find the strength of the rivets, taking 3 rivets, thus 3 times .7854 d^2, then by the factor .821, and then by the tensile strength of the plate material in pounds per square inch.
7. Find the strength of the original plate, by taking the pitch times the thickness, and then by the tensile strength of the plate material in pounds per square inch.
8. Find the efficiency of the joint, by taking the weaker, plates or rivets, and dividing by the result of 7.

NOTE:—In Boiler work this type of joint should have a value of pitch not greater than $P = 3.47\ t + 1\frac{5}{8}$ inches.

The size of rivets to the thickness of the plate remains as for joints 1 and 2, vis: $d = 1.5\ t$ to $d = 2.5\ t$.

JOINT 4
TRIPLE RIVETED LAP JOINT
RIVETS IN MIDDLE ROW SPACED ½ PITCH



Cut 22.

The element on which strength is figured is ABCD, colored for identification. This element contains four rivets, and compared to Joint 3, has an extra rivet therein and accordingly stronger.

In this case the diagonal pitch, "X," becomes:

X not less than $.3\ P + d$.

And accordingly the horizontal distance between rows "Y" is:

Y not less than $\sqrt{(.55\ P + d)\ (.05\ P + d)}$.

And the Lap is: $3d + 2\ Y$.

Strength of Plate $= t\ (P - d) \times UT$.
Strength of Rivets $= 4 \times .7854\ d^2 \times US$.

For equal strength of plate and Rivets, we get:

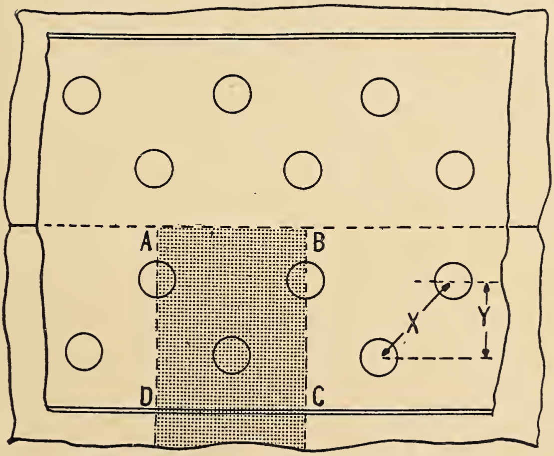
$tP - td = 3.1416\, d^2 \times US/UT$, and if we take the former ratio of .821,
$P = d\,(1 + 2.58\, d/t)$.

And to figure this joint:

1. Select a rivet according to the thickness of the plate.
2. Find the pitch using the above formula.
3. Find the diagonal pitch as above.
4. Find the distance between rows, as above.
5. Find the strength of the plate, subtracting the diameter of One rivet from the pitch then times the thickness, and then by the tensile strength of the plate material in pounds per square inch.
6. Find the strength of the rivets, taking 4 times the strength of one vis, 4 times .7854 d^2, then times .821, and then by the tensile strength of the plate material in pounds per square inch.
7. Find the strength of the unpunched plate, taking pitch times thickness, and then by the tensile strength of the plate material in pounds per square inch.
8. Find the efficiency of the joint, by taking the lower of the two, plate or rivets, and dividing by the result in 7.

NOTE:—In Boiler work in this joint, pitch should not be greater than
$P = 4.14\, t + 1\tfrac{5}{8}$ inches.
The ratio of d to t remains $d = 1.5\, t$ to $d = 2.5\, t$.

JOINT 5
TRIPLE RIVETED BUTT JOINT DOUBLE BUTT STRAPS



Cut 23.

The element on which strength is figured is ABCD, colored for identification, and note should be taken that the arrangement of the rivets is duplicated on either side of the Joint. It is only necessary to figure the strength of one side as shown. The Rivets are in double shear, and for rivets in double shear it is customary to give double the value for single shear, but as we have used figures of the British Board of Trade, and they specify double shear as $1\tfrac{3}{4}$ times the value for single shear we will use that figure. The element contains one whole rivet and two half rivets a total of 2 rivets.

In butt joints the thickness of each strap or cover plate must not be less than $\tfrac{5}{8}$ times the thickness of the plate. This is for a double butt strapped joint. Experimentation has demonstrated that the straps are weaker than the plate proportionally. That is it is not proper to make each double butt strap $\tfrac{1}{2}$ the thickness of the plate. In the case of single straps, the thickness should be $1\tfrac{1}{8}$ times the thickness of the plate, at least.

For this joint the diagonal pitch is

$$X \text{ not less than } (.6\ P + .4\ d)$$

And the distance between rows,

$$Y \text{ not less than } \sqrt{(1.1\ P + .4d)\ (.1\ P + .4d)}$$

The width of the butt straps are:

$$6\ d + 2\ Hy = \text{Width of butt straps.}$$

$$\text{STRENGTH OF PLATE} = t\ (P - d) \times UT.$$

$$\text{STRENGTH OF RIVETS} = 2 \times .7854d^2 \times US \times 1.75.$$

For equal strength of plate and rivets:

$tP - td = 2.75\ d^2\ US/UT$, and taking the figure .821,

$$P = d\ (1 + 2.26\ d/t)$$

And to figure this joint:

1. Select a rivet according to the thickness of the plate.

2. Find the pitch using the above formula.

3. Find the diagonal pitch using the above formula.

4. Find the distance between rows as above.

5. Find the thickness of the cover plates, vis plate thickness times ⅝.

6. Find the width of the cover plates, vis $6\ d + 2\ Y$.

7. Find the strength of the plate, substracting the diameter of one rivet from the pitch, multiplying by the thickness of the plate, and then by the tensile strength of the plate material in pounds per square inch.

8. Find the strength of the rivets, by taking two rivets in double shear, thus 2 times $.7854\ d^2$, times 1.75, the ratio of double shear to single shear, times .821 the ratio of US/UT, and then times the tensile strength of the plate material in pounds per square inch.

9. Find the strength of the original plate, by taking the pitch times the thickness times the tensile strength of the plate material in pounds per square inch.

10. Find the efficiency of the joint, by taking the weaker of the two, plate or rivets, and dividing by the result of 9.

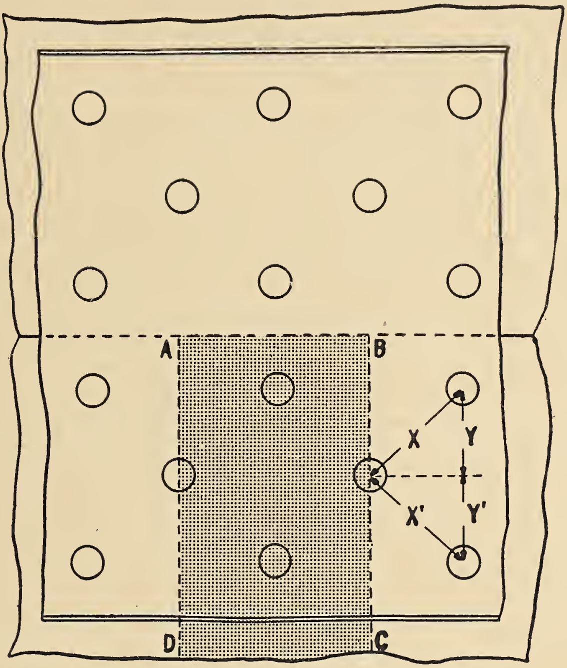
NOTE:—For boiler work the value of the pitch should not be greater than,

$$P = 3.5\ t + 1\tfrac{5}{8} \text{ inches.}$$

In this type of joint the ratio of the diameter of the rivet "d," to the thickness of the plate "t," ranges from $d = 1\ t$, up to $d = 1.25\ t$. The lower value, as compared to rivets in lap joint in single shear, is necessary to guard against the danger of crushing.

JOINT 6

TRIPLE RIVETED BUTT JOINT DOUBLE BUTT STRAPS



Cut 24.

The element on which strength is figured is ABCD, colored for identification. The rivets are in double shear, and the thickness of the Butt plates not less than $\frac{5}{8}$ t., each. The element contains two whole rivets, and two half rivets, a total of 3 rivets.

In this case the Diagonal Pitch is:

$$X \text{ not less than } (.6\,P + .4\,d)$$

And the Horizontal distance between Rows:

$$Y \text{ not less than } \sqrt{(1.1\,P + .4\,d)\,(.1\,P + .4\,d)}.$$

And the total width of the Butt Plates is:

$$6\,d + 4\,H.$$

$$\text{Strength of Plate} = t\,(P - d)\,UT.$$

$$\text{Strength of Rivets} = 3 \times .7854\,d^2\,US. \times 1.75.$$

For equal strength of Plate and Rivets:

$$tP - td = 4.15\,d^2 \times US/UT.$$

If we take our former ratio of .821 for US/UT, and 1.75 as the value of Double Shear compared to Single Shear we get:

$$P = d\,(1 + 3.39\,d/t).$$

To figure this Joint:

1. Select a rivet according to the thickness of the plate.
2. Find the pitch using the above formula.
3. Find the diagonal pitch as above.
4. Find the distance between rows, as above.
5. Find the width of the Butt straps as above.
6. Find the thickness of the Butt straps, vis. $t \times \frac{5}{8}$.
7. Find the strength of the plate, substracting the diameter of one rivet from the pitch, multiplying by the thickness, and then by the tensile strength of the plate material in pounds per square inch.
8. Find the strength of the rivets, taking three rivets, times the area of one, vis $3 \times .7854\ d^2$, then by 1.75 the ratio for double shear, then by .821 the ratio of US/UT, and then by the tensile strength of the plate material in pounds per square inch.
9. Find the strength of the unpunched plate, by taking the pitch times the thickness, and then times the tensile strength of the plate material in pounds per square inch.
10. Find the efficiency of the joint, by taking whichever is the weaker of the two, plates or rivets, and dividing by the results as found in "9."

NOTE:—For Boiler work using this joint the pitch should never be greater than:

$$P = 4.63 + 1\tfrac{5}{8} \text{ inches.}$$

The ratio of d to t is $d = 1\ t$ to $d = 1.25\ t$. The lower value to guard against crushing.

Note should be taken in all of these joints that it would be possible to use assumed values for shearing strength of rivets, and to use the ratio of twice this value for single shear for the value in double shear. The use of factors is evident, and as explained the tensile strength of plate is always stamped on the furnished plate. For example of the values customary to use we quote:

Tensile Strength of Plate Material. . .55000 lbs. per square inch.

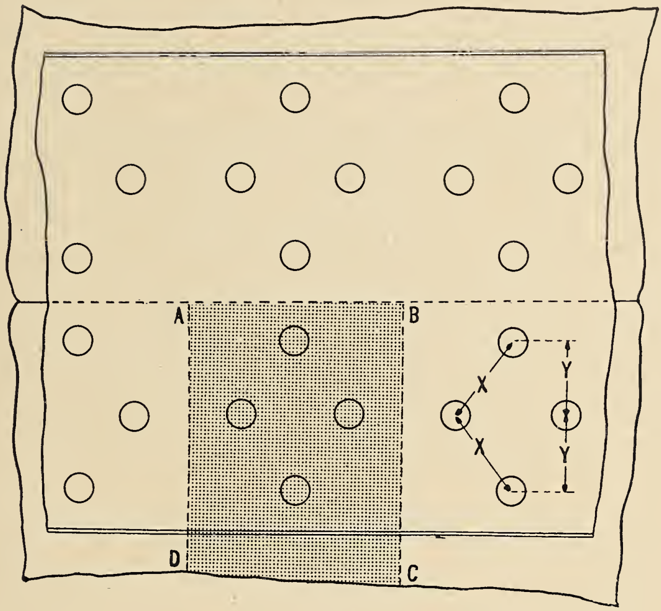
Single Shear Strength of Rivet. . . . . .44000 lbs. per square inch.

Double Shear Strength of Rivets. . . . .88000 lbs. per square inch.

Crushing Strength of Plate. . . . . .95000 lbs. per square inch.

JOINT 7

TRIPLE RIVETED BUTT JOINT, DOUBLE BUTT PLATES, WITH THE RIVETS IN THE MIDDLE ROW ON EITHER SIDE OF THE JOINT SPACED 1/2 PITCH



Cut 25.

The element on which strength is figured is ABCD, colored for identification. The rivets are in double shear, and the joint is similar to Joint 6, excepting that the element contains four whole rivets.

In this case the Diagonal pitch is:

$$X \text{ not less than } (.3\,P + .4\,d).$$

And the distance between rows is:

$$Y \text{ not less than } \sqrt{(.55\,P + d)\,(.05\,P + d)}.$$

In this case the thickness of the Butt straps must not be less than

$$\text{Thickness of Straps} = \tfrac{5}{8}\,(P - d) \div (P - 2d) \times t.$$

The total width of the Butt straps is:

$$\text{Width} = 6\,d + 4\,X.$$

$$\text{Strength of Plate} = t\,(P - d)\,UT.$$

$$\text{Strength of Rivets} = 4 \times .7854\,d^2\,US \times 1.75.$$

For equal strength of plate and rivets we get:

$tP - td = 5.5\ d^2\ US/UT \times$, and if we take the ratio of .821 we get:

$$P = d\,(1 + 4.52\ d/t).$$

To figure this joint:

1. Select a rivet according to the thickness of the plate.

2. Find the pitch using the above formula.

3. Find the diagonal pitch as above.

4. Find the distance between rows, as above.

5. Find the thickness of the Butt straps, as above.

6. Find the width of the Butt straps as above.

7. Find the strength of the punched plate, substracting the diameter of the rivet, or rivet hole from the pitch, multiplying by the thickness of the plate, and then by the tensile strength of the plate material in pounds per square inch.

8. Find the strength of the rivets, in this case taking 4 rivets in double shear, vis $4 \times .7854\ d^2$, $\times$ 1.75 the ratio of double shear to single shear, times .821 the ratio of US/UT, and then times the tensile strength of the plate material in pounds per square inch.

9. Find the strength of the plate material unpunched, by multiplying the pitch by the thickness and then by the tensile strength of the plate material in pounds per square inch.

10. Find the efficiency of the joint by taking whichever is the lower of the two, plate or rivets, and dividing by the result as found in "9."

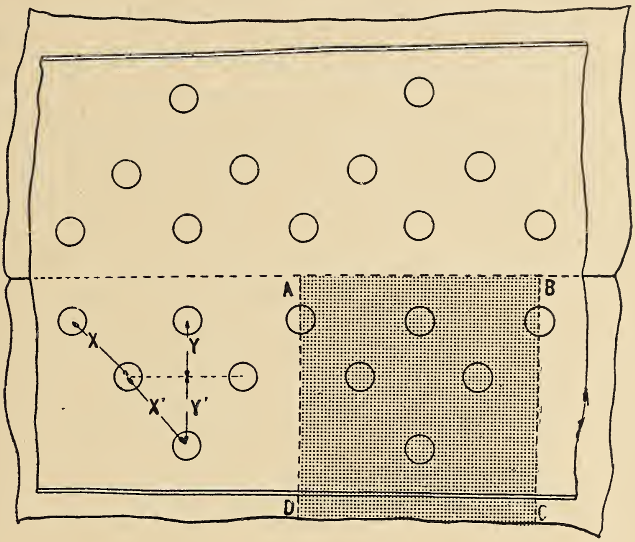
NOTE:—For Boiler work the value of the pitch should never be greater than:

$$P = 5.52\ t + 1\tfrac{5}{8}\ \text{inches}.$$

In this type of joint the ratio of d to t, is $d = 1\ t$, up to $d = 1.25\ t$.

JOINT 8

TRIPLE RIVETED BUTT JOINT, DOUBLE BUTT STRAPS, WITH DOUBLE SPACING OF RIVETS IN THE OUTER ROW ON EACH SIDE



Cut 26.

The element on which strength is figured is ABCD, colored for identification. The rivets are in double shear, and the joint contains four whole rivets and two half rivets, a total of 5 rivets. In this case the pitch is the distance between rivets in the outer row, thus the double spacing of the rivets in the outer row is the figured pitch, and the two inner rows considered as spaced ½ pitch. In this case there are two sets of diagonal pitch, one for the distance between the first two rows, and another value for the distance between the second and third row.

In this case the diagonal pitch of the first and second row, figured from the joint, is X, and should not be less than:

$$X \text{ not less than } .3\ P + .4\ d.$$

And the diagonal pitch between the second and third row, denoted by X′, should not be less than:

$$X' \text{ not less than } .3\ P + d.$$

Accordingly the horizontal distance between the first and second row is Y, and should not be less than:

$$Y \text{ not less than } \sqrt{(.55\ P + .4\ d)\ (.05\ P + .4\ d)}.$$

And the horizontal distance between rows for the second and third row Y′ should not be less than

$$Y' \text{ not less than } \sqrt{(.55\ P + d)\ (.05\ P + d)}.$$

The thickness of the Butt straps should not be less than:

$$\text{Thickness} = \tfrac{5}{8} (P - d) \div (P - 2 d) \times t.$$

The width of the Butt straps is:

$$\text{Width} = 6 d + 2 Y + 2 Y'.$$

$$\text{Strength of the Plate} = t (P - d) UT.$$

$$\text{Strength of Rivets} = 5 \times .7854 d^2 US \times 1.75.$$

For equal strength of plate and rivets we get:

$tP - td = 6.875 d^2 US/UT.$, and if we take our former ratio of .821 we get:

$$P = d (1 + 5.64 d/t).$$

To design this joint:

1. Select a rivet according to the thickness of the plate.
2. Find the pitch using the above formula. This is the pitch of the outer row, and the inner rows are spaced $\frac{1}{2}$ this value.
3. Find the diagonal pitch X., and the diagonal pitch X$'$.
4. Find the distance between rows, Y and Y$'$.
5. Find the total width of the Butt straps, as above.
6. Find the thickness of the Butt straps as above.
7. Find the strength of the punched plate, by taking the diameter of one rivet hole from the pitch, multiplying by the thickness and then by the tensile strength of the plate material in pounds per square inch.
8. Find the strength of the rivets, taking 5 rivets in double shear, thus 5 times .7854 d^2 times 1.75 the ratio of double to single shear, then times .821 the ratio of US/UT, and then by the tensile strength of the plate material in pounds per square inch.
9. Find the strength of the unpunched plate, by taking the pitch times the thickness of the plate, and then times the tensile strength of the plate material in pounds per square inch.
10. Find the efficiency of the joint by taking whichever is the weaker plate or rivets and dividing by the results of "9."

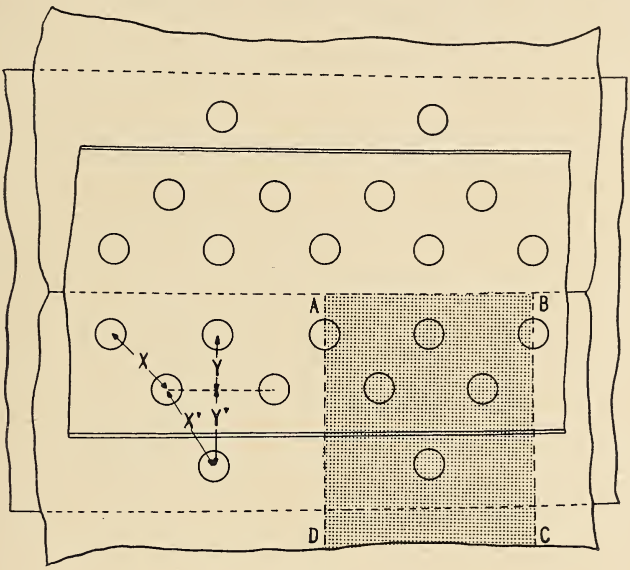
NOTE:—For Boiler work and using this joint, the pitch should never be greater than:

$$P = 6.00 t + 1\tfrac{5}{8} \text{ inches.}$$

The ration of d to t, stays the same as for previous Butt joints, in that $d = 1 t$ to $d = 1.25 t$.

JOINT 9

TRIPLE RIVETED BUTT JOINT, DOUBLE BUTT STRAPS, THE OUTER ROW OF RIVETS BEING DOUBLE SPACED AND PASSING THROUGH THE INSIDE BUTT STRAP ONLY



Cut 27.

The element on which strength is figured is ABCD, colored for identi- ycation. The rivets in the two inner rows are in double shear, and the rivets in the outer row are in single shear. There are thus four rivets in double shear, and one rivet in single shear in this element. Rivets are spaced $1\frac{1}{2}$d, from the edge of any plate, as has been done in all the joints considered.

In this joint there are two diagonal pitches X and X′, the value of which are as follows:

X not less than .3 P + .4 d.

X′ not less than .3 P + d.

And the horizontal distance between rows becomes Y and Y′, the values of which are:

Y not less than $\sqrt{(.55\ P + .4\ d)\ (.05\ P + .4\ d)}$

Y′ not less than $\sqrt{(.55\ P + d)\ (.05\ P + d)}$.

The width of the upper and smaller Butt strap is:

Width = 6 d + 2 Y.

And the width of the under Butt strap is:

Width = 6 d + 2 Y + 2 Y′.

The thickness of the Butt straps are not less than:

Thickness = $\frac{5}{8}$ (P — d) ÷ (P — 2d) × t.

Strength of the Plate $= t \times (P - d) \times UT$.

Strength of Rivets $= 4 \times .7854\, d^2\, US \times 1.75 + 1 \times .7854\, d^2\, US$.

thus Strength of Rivets $= 8 \times .7854\, d^2\, US$.

For equal strength of plate and rivets we get:

$tP - td = 6.28\, d^2\, US/UT$, and if we take our former ratio of .821 we get:

$$P. = d\,(1 + 5.16\, d/t).$$

To design this joint proceed as follows:

1. Select a rivet according to the thickness of the plate.
2. Find the pitch using the above formula. This pitch is the distance center to center of the rivets in the outer row. The inner rows are spaced $\frac{1}{2}$ pitch.
3. Find the diagonal pitch X, between the two inner rows, and the value X′ for the diagonal pitch between the middle and the outer row.
4. Find the horizontal distance Y, between the two inner rows, and the distance Y′ for the distance between the middle row and the outer row.
5. Find the thickness of the Butt straps using the above formula.
6. Find the width of the under Butt strap as above.
7. Find the width of the upper Butt Strap as above.
8. Find the strength of the plate as punched, by subtracting the diameter of one rivet from the pitch, multiplying by the thickness of the plate and then by the tensile strength of the plate material in pounds per square inch.
9. Find the strength of the rivets, in this case there being four rivets in double shear and the equivalent of one rivet in single shear. Thus, 4 times $.7854\, d^2$, times 1.75 the ratio of double to single shear, times .821 the ratio of US/UT, times the tensile strength of the plate material in pounds per square inch, gives the value for the four rivets in double shear. Add to this value the value of one rivet in single shear, which is 1 times $.7854\, d^2$, times .821 times the tensile strength of the plate material in pounds per square inch.
10. Find the strength of the unpunched plate, by taking the pitch times the thickness of the plate, times the tensile strength of the plate material in pounds per square inch.
11. Find the efficiency of the joint, by taking whichever is the weaker of the two, plate or rivets, and dividing by the result of "10."

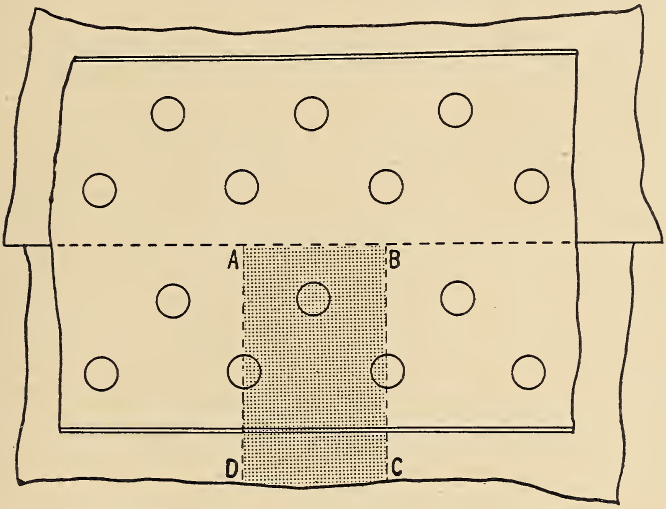
NOTE:—In this type of joint when used for Boiler work the pitch should never be greater than:

$$P = 6.00\, t + 1\tfrac{5}{8} \text{ inches}.$$

In this type of joint the value of d ranges from $d = 1\, t$, to $d = 1.25\, t$.

JOINT 10

DOUBLE RIVETED, SINGLE STRAPPED, BUTT JOINT



Cut 28.

The element on which strength is figured is ABCD, colored for identification. The rivets are in single shear, and placed $1\frac{1}{2}$d from the edges of the plate. The cover plate is made $1\frac{1}{8}$ t, in thickness. In other respects this joint is similar to a Lap joint having the same number of rows of rivets. This element contains one whole rivet and two half rivets.

$$\text{Strength of Plate} = t\,(P - d)\ UT.$$

$$\text{Strength of Rivets} = 2 \times .7854\ d^2\ US.$$

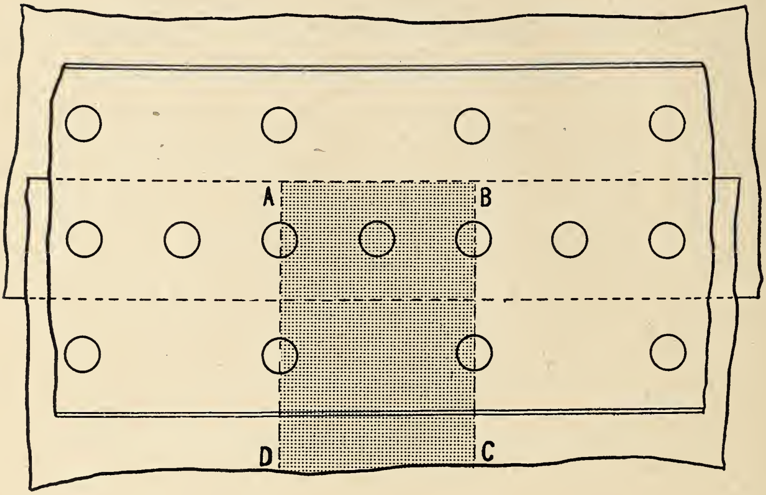
For equal strength of plate and rivets:

$tP - td = 1.5708\ d^2\ US/UT$, and if we take the ratio of .821 as before we get:

$$P = d\,(1 + 1.29\ d/t).$$

NOTE:—This joint is subject to a bending action, and with the butted joint tending to aid the action of bending.

JOINT 11
COMBINED LAP AND BUTT JOINT



Cut 29.

The element on which strength is figured is ABCD, and note should be taken that this represents the entire lap. The strength of this joint is aided by the rivets in the center row being in double shear. The element contains 1 rivet in single shear, and two rivets in double shear.

Strength of Plate $= t\,(P - d)\,UT.$

Strength of Rivets $= 1 \times .7854\,d^2\,US + 2 \times .7854\,d^2\,US \times 1.75.$

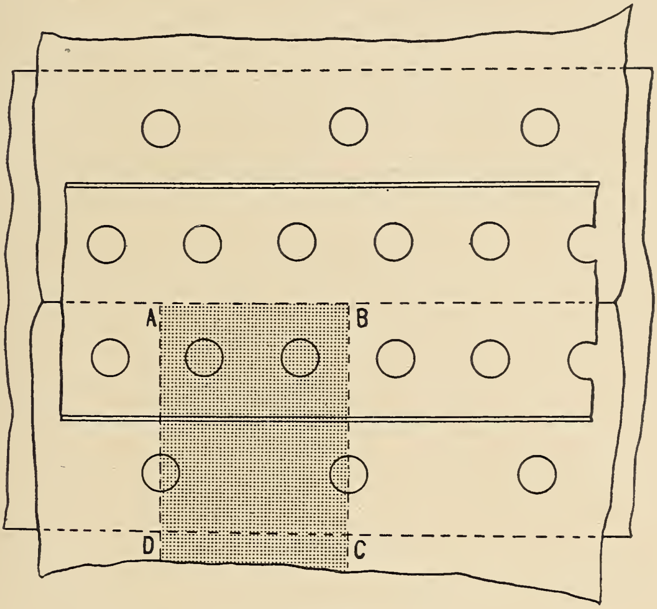
For equal strength of plate and rivets we get:

$tP - td = 3.5343\,d^2\,US/UT$, and if we take our former ratio of .821 we get:

$P = d\,(1 + 2.89\,d/t).$

JOINT 12

DOUBLE RIVETED, DOUBLE BUTT STRAPS, BUTT JOINT, WITH CHAIN ARRANGEMENT OF RIVETS. PITCH OF INNER ROW 1/2 PITCH. OUTER RIVETS PASSING THROUGH UNDER COVER PLATE ONLY



Cut 30.

The element on which strength is figured is ABCD, colored for identification. This element contains two rivets in double shear, and two half rivets in single shear.

Strength of Plate $= t\ (P - d)\ UT.$

Strength of Rivets $= 2 \times .7854\ d^2 \times US \times 1.75 + 1 \times .7854\ d^2\ US.$

For equal strength of plate and rivets we get:

$$tP - td = 3.53\ d^2\ US/UT.$$

and if we take the former ratio of .821 for US/UT, we get:

$$P = d\ (1 + 2.90\ d/t).$$

In this joint the width of the upper Butt strap is:

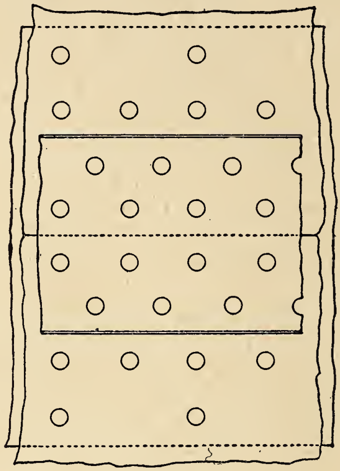
$$\text{Width} = 6\ d.$$

And the width of the under Butt strap is:

$$\text{Width} = 12\ d.$$

The rest of the design is similar to the foregoing.

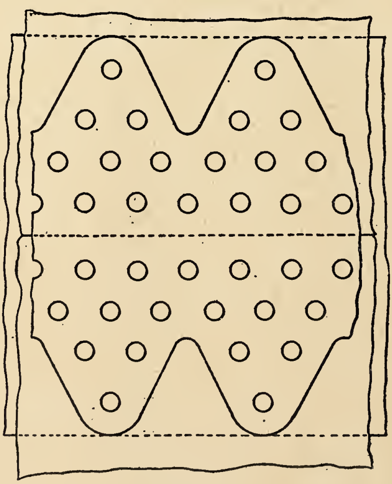
JOINT 13
QUADRUPLE RIVETED, DOUBLE STRAPPED, BUTT JOINT, WITH STRAPS OF EQUAL WIDTH



Cut 31.

This type of joint is used to avoid eccentric stresses. Properly designed this joint will yield an efficiency of from 82 to 84%.

JOINT 14
QUADRUPLE RIVETED, DOUBLE STRAPPED BUTT JOINT, UPPER STRAP MADE SAW TOOTH



Cut 32.

This type of joint also is one to use to avoid eccentric stresses, and properly proportioned yields an efficiency of as high as 94%.

THE EFFICIENCY OF JOINTS

Taking concrete sizes of rivets and thickness of plates the following values for efficiency are obtained. The first nine are figured according to the British Board of Trade method, and the last 5 are figured according to the Boiler Code of the A. S. M. E method. The Boiler Code permits of using 55000 lbs. for the tensile strength of plate, 44000 lbs. for the value of single shear, and 88000 lbs. for double shear, and allows 95000 lbs. as the crushing resistance.

Joint.	Type.	Riveting.	Size Rivets.	Thickness of Plate.	Pitch.	Efficiency.
1.	Lap.	Single.	$\frac{7}{8}''$	$\frac{1}{2}''$	$1\frac{7}{8}''$	52.5%
2.	Lap.	Double.	$\frac{7}{8}''$	$\frac{1}{2}''$	$2\frac{7}{8}''$	68.7%
3.	Lap.	Triple.	$\frac{7}{8}''$	$\frac{1}{2}''$	$3\frac{7}{8}''$	76.4%
4.	Lap.	Triple.	$\frac{7}{8}''$	$\frac{1}{2}''$	$2\frac{7}{16}''$ Middle $4\frac{7}{8}''$ Outer	81.0%
5.	Butt.	Double.	$1\frac{1}{4}''$	$1''$	$4\frac{3}{4}''$	73.7%
6.	Butt.	Triple.	$1\frac{3}{16}''$	$1''$	$6''$	79.6%
7.	Butt.	Triple.	$1\frac{5}{8}''$	$1\frac{1}{2}''$	$9\frac{5}{8}''$ Outer $4\frac{13}{16}''$ Inner	82.6%
8.	Butt.	Triple.	$1\frac{7}{16}''$	$1\frac{3}{8}''$	$10''$ Outer $5''$ Inner	84.8%
9.	Butt.	Triple.	$1\frac{7}{16}''$	$1\frac{3}{8}''$	$9\frac{1}{4}''$ Outer $4\frac{5}{8}''$ Inner	83.8%
1.	Lap.	Single.	$\frac{11}{16}''$	$\frac{1}{4}''$	$1\frac{5}{8}''$	57.6%
2.	Lap.	Double.	$\frac{3}{4}''$	$\frac{5}{16}''$	$2\frac{7}{8}''$	73.9%
12.	Butt.	Double.	$\frac{7}{8}''$	$\frac{3}{8}''$	$4\frac{7}{8}''$ Outer $2\frac{7}{16}''$ Inner	82.0%
9.	Butt.	Triple.	$\frac{13}{16}''$	$\frac{3}{8}''$	$6\frac{1}{2}$ Outer $3\frac{1}{4}''$ Inner	87.5%
14.	Butt.	Quadruple.	$\frac{15}{16}''$	$\frac{1}{2}''$	$15''$ Outer $7\frac{1}{2}''$ Second $3\frac{3}{4}''$ Inner	93.7%

CHAPTER VI

STEAM BOILER CONSTRUCTION

Up until approximately 1890, the requirements for steel in boiler manufacture was specified solely by brand, and such terms as were applied were often indefinite and the steel bought on faith rather than on knowledge. Increase in Boiler Working Pressure made it necessary to adopt standards, the first standard being that of the American Boiler Manufacturers Association compiled in the latter part of 1889. These standards were modernized from time to time with increase in knowledge, and their example was followed particularly by the State Authorities, resulting in a vast number of Standard Specifications. For the past five years efforts to establish a Standard Boiler Code in all states by this pioneer in the matter, the Boiler Makers Association, have been made, and resulting in the adoption of, "Rules for the Construction of Steam Boilers," as compiled by the Boiler Code Committee of the American Society of Mechanical Engineers in many states. The widely different regulations in the various states lead to much confusion, and it was not to be wondered at that the death toll from boiler explosions amounted to from 400 to 500 persons killed per annum. For safety sake a standardized rule for all states is a necessity.

There was much prejudice against Steel Rivets, when they were first introduced in the late 80's, and which lasted for a number of years, and in the first utilization of Steel Plates for Boilers there were many absurd results from the use of high grade charcoal iron rivets with them. The prejudice was finally overcome largely through the efforts of the Severance Mfg. Co. in demonstrating the proper methods of heating and driving steel rivets, which naturally is different from that of the driving of iron rivets. Rivets are now made of the same high quality steel that enters into other parts of boiler construction, and the standards for which have been quoted in Chapter IV.

There are two classes of boilers in general use, namely, water tube and fire tube. In the water tube boiler the water is contained in the tubes and the fire circulates outside them. In the fire tube boiler the water is contained in the shell and the fire passes through the tubes which are in the water and attached to the heads. The return tubular boiler is a type of fire tube boiler.

There are three grades of steel for boilers, namely, Flange, Firebox, and Boiler Rivet. The chemical composition and physical properties are as follows, attention being drawn to the listed specifications given in Chapter IV.

BOILER STEEL

	Flange	Firebox	Rivet
Manganese	0.30 to 0.60	0.30 to 0.50	0.30 to 0.50
Phosphorous Basic, max	.040	.035	.040
Phosphorous Acid, max	.050	.040	.040
Sulphur, max	.050	.040	.045
Tensile strength, lbs. sq. in	55000 to 65000	52000 to 60000	45000 to 55000
Yield point, lbs. sq. in	½ TS.	½ TS.	½ TS.
Elongation in 8″, min. %	1450000 ÷ TS.	1450000 ÷ TS.	1450000 ÷ TS.
Cold Bend	(*)	(*)	180° Flat
Quench Bend	(*)	(*)	180° Flat

(*)—For Flange and Fire Box material the Cold and the Quench bends are as follows:—

Up to ¾″ in thickness and including ¾″ bend 180° flat.

From ¾″ up to 1¼″ bend around a pin the diameter of which is equal to the thickness of the test piece.

Above 1¼″ in thickness bend around a pin 1½ times the thickness of the test piece.

These bends to be accomplished without fracture or cracking on the outside of the bent portion.

As the size of rivets customary to be used is predicated upon the thickness of the plate, we give the following table of variations allowed in plate thickness and weight as standardized by the Association of American Steel Manufacturers in Cut 33. We also give the minimum thickness allowed in Boiler Construction from the Boiler Code.

Thickness of Plates

The minimum thickness of any Boiler plate under pressure shall be ¼″.

The minimum thickness of Shell plates and Dome plates after flanging shall be:

When the diameter is:

36″ or under.	From 36″ to 54″	From 54″ to 72″	Over 72″
¼″	5/16″	⅜″	½″

The Association of American Steel Manufacturers

MANUFACTURERS' STANDARD PRACTICE

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS OF SHEARED PLATES

One cubic inch of rolled steel is assumed to weigh 0.2833 pound.

WHEN ORDERED TO WEIGHT PER SQUARE FOOT: The weight of each lot [1] in each shipment shall not vary from the weight ordered more than the amount given in the following table:

Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights

Ordered Weight Lbs. per Sq. Ft.	Under 48 in.		48 to 60 inches exclusive		60 to 72 inches exclusive		72 to 84 inches exclusive		84 to 96 inches exclusive		96 to 108 inches exclusive		108 to 120 inches exclusive		120 to 132 inches exclusive		132 to 144 inches exclusive		Ordered Weight Lbs. per Sq. Ft.
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	
Under 5	5	3	5.5	3	6	3	7	3											Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3											5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3					7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1⅓ times the amount given in this table.

[1] The term "lot" applied to this table means all of the plates of each group width and group weight.

WHEN ORDERED TO THICKNESS: The thickness of each plate shall not vary more than 0.01 in. under that ordered. The overweight of each lot [2] in each shipment shall not exceed the amount given in the following table:

Permissible Excess in Average Weights Per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights

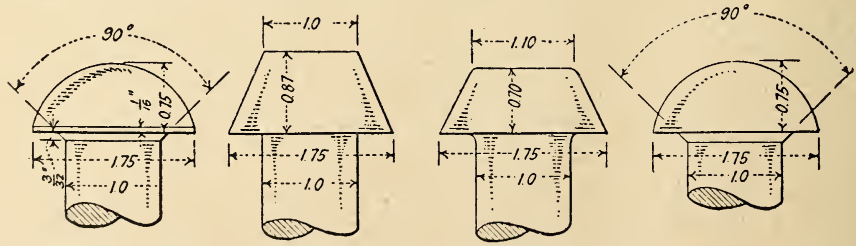
Ordered Thickness Inches	Under 48 in.	48 to 60 inches exclusive	60 to 72 inches exclusive	72 to 84 inches exclusive	84 to 96 inches exclusive	96 to 108 inches exclusive	108 to 120 inches exclusive	120 to 132 inches exclusive	132 to 144 inches exclusive	Ordered Thickness Inches
Under 1/8	9	10	12	14						Under 1/8
1/8 to 3/16 excl.	8	9	10	12						1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12					3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

[2] The term "lot" applied to this table means all of the plates of each group width and group thickness.

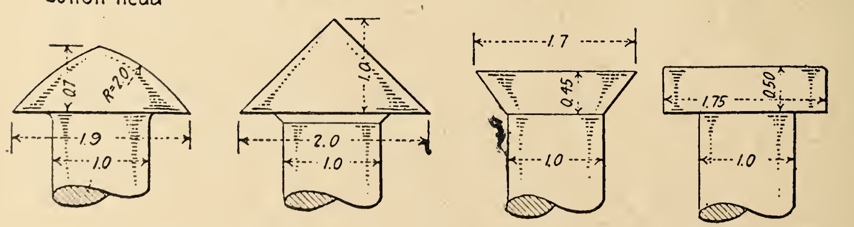
Cut 33.

FORM OF BOILER RIVET HEADS

The following are acceptable forms of heads of rivets entering into Boiler construction, as allowed by the Boiler Code.



Straight Base Button Head　　Cone Head　　Pan Head　　Button Head



Double Radius Button Head　　Steeple Head　　Countersunk Head　　Flat Head

Dimensions may be larger or 1/10 smaller than those shown.
Fillets under heads may be used but are not required.

Cut 34.

DIAMETER OF RIVETS COMPARED TO THE THICKNESS OF THE PLATE

In the design of Joints as given in Section 4, the ratio of d to t, was given. There are numerous rules for this relationship, and an additional rule to that given is:

$$d = \frac{3}{4}t + \frac{3}{8}'' \quad \text{to} \quad d = \frac{7}{8}t + \frac{3}{8} \text{ inches.}$$

Unwins rule is:

$$d = 1.2\sqrt{t}.$$

The Boiler Code quotes the following table:

TABLE OF SIZES OF RIVETS BASED ON THICKNESS OF THE PLATE

Thickness of Plate, inches.	Diameter of Rivet after driving.
$\frac{1}{4}''$	$\frac{11}{16}''$
$\frac{9}{32}''$	$\frac{11}{16}''$
$\frac{5}{16}''$	$\frac{3}{4}''$
$\frac{11}{32}''$	$\frac{3}{4}''$
$\frac{3}{8}''$	$\frac{13}{16}''$
$\frac{13}{32}''$	$\frac{13}{16}''$
$\frac{7}{16}''$	$\frac{15}{16}''$
$\frac{15}{32}''$	$\frac{15}{16}''$
$\frac{1}{2}''$	$\frac{15}{16}''$
$\frac{9}{16}''$	$1\frac{1}{16}''$
$\frac{5}{8}''$	$1\frac{1}{16}''$

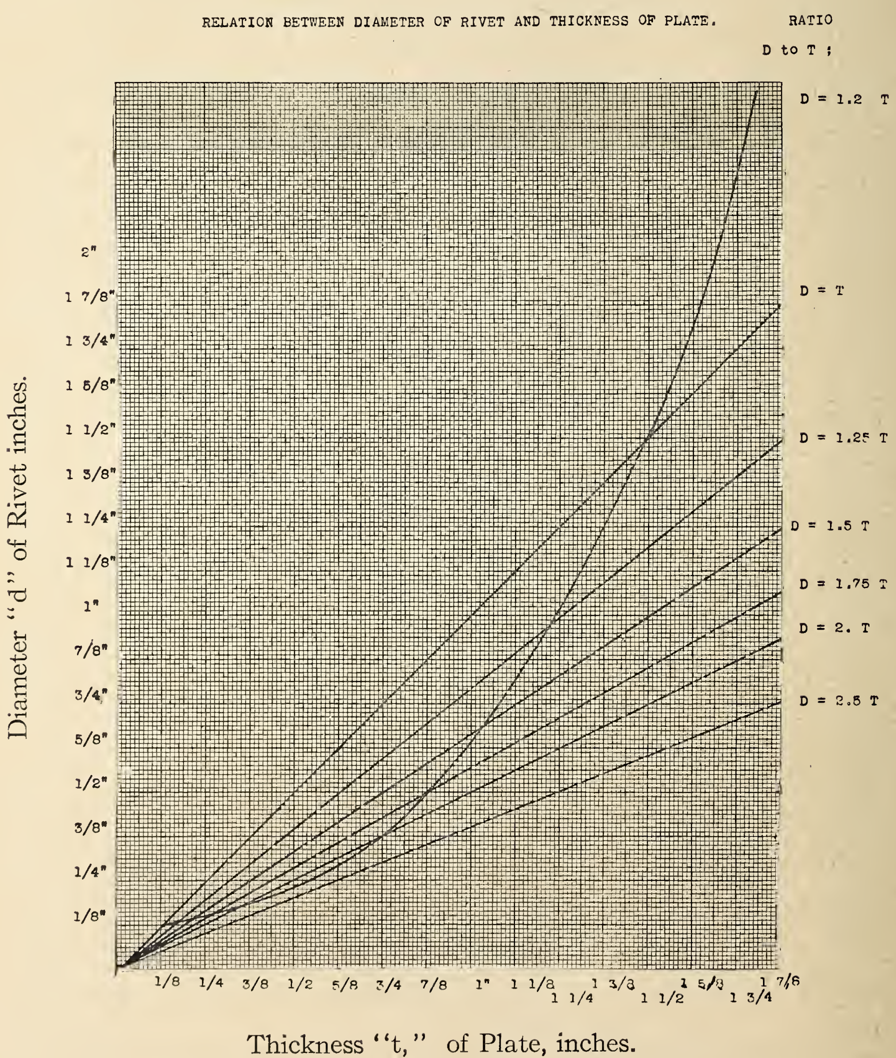
Boilers up to 14 feet in length are made of two plates, each forming half the length of the boiler. Above 14 feet 3 plates are used to give the total length. These plates are $\frac{1}{4}''$, $\frac{3}{8}''$, $\frac{1}{2}''$, or $\frac{9}{16}''$ thick.

In boiler practice if the plates are too thick they will not transfer the heat rapidly, and expansion and contraction strains also become severe. This contraction on the longer rivets required tends to cause them to become loose, and in addition to this defect thick plates are very apt to burn. All things considered the thinner the plate consistant with strength the better.

The effect of heat on boiler and on rivet steels is to decrease the strength up to approximately 250°, then to increase the strength up to approximately 600°, and then to rapidly decrease the strength beyond that point.

In horizontal return tubular boilers with Lap Joints, no course is permitted to be over 12 feet in length. With Butt and Double Strap construction longitudinal joints of any length may be used, provided the tension test specimens are so cut from the shell plate and that their lengthwise direction is parallel with the circumferential seams of the boiler, and that these tests meet the standard requirements as given in the specifications for Boiler Plate.

The curves as given in Cut 35, afford a quick means of determining the size of rivet to use for a given thickness of plate. With a given plate, as given on the bottom line in inches. Follow up to intersection of Heavy Lined Curve, of the selected ratio d = 1.25 t, d = 1.5 t, etc., and thence horizontally to vertical figures, which gives rivet diameter, in inches. In case of intersection giving a rivet of odd size select one 1/16″ larger in diameter, but remembering that rivets in 1/16″ sizes are special, whereas those given are stock sizes.



Cut 35.

Strength of Rivets in Shear

The Boiler Code specifies that the cross sectional area used in computations shall be the area of the Rivet shank after driving. It allows the following values for shearing strength:

Iron Rivets in Shingle Shear ....38000 lbs. per sq. in.
Iron Rivets in Double Shear..........76000 lbs. per sq. in.
Steel Rivets in Single Shear...........44000 lbs. per sq. in.
Steel Rivets in Double Shear..........88000 lbs. per sq. in.

Thickness of Butt Straps.

The minimum thickness of Butt straps for Double Butt Strap Joints is as per the following table. For intermediate values interpolate. For plate thickness exceeding $1\frac{1}{4}$ inches, the thickness of the Butt Straps shall not be less than 2/3 the thickness of the plate.

Butt Straps and the ends of shell plates forming longitudinal joints in a boiler must be rolled or formed by pressure, and not by blows, to the proper curvitures.

Minimum Thickness of Butt Straps.

Thickness of Steel Plates, inches.	Minimum Thickness of Butt Straps, inches.
$\frac{1}{4}''$	$\frac{1}{4}''$
$\frac{9}{32}''$	$\frac{1}{4}''$
$\frac{5}{16}''$	$\frac{1}{4}''$
$\frac{11}{32}''$	$\frac{1}{4}''$
$\frac{3}{8}''$	$\frac{5}{16}''$
$\frac{13}{32}''$	$\frac{5}{16}''$
$\frac{7}{16}''$	$\frac{3}{8}''$
$\frac{15}{32}''$	$\frac{3}{8}''$
$\frac{1}{2}''$	$\frac{7}{16}''$
$\frac{17}{32}''$	$\frac{7}{16}''$
$\frac{9}{16}''$	$\frac{7}{16}''$
$\frac{5}{8}''$	$\frac{1}{2}''$
$\frac{3}{4}''$	$\frac{1}{2}''$
$\frac{7}{8}''$	$\frac{5}{8}''$
$1''$	$\frac{11}{16}''$
$1\frac{1}{8}''$	$\frac{3}{4}''$
$1\frac{1}{4}''$	$\frac{7}{8}''$

The stress upon the longitudinal seams is greater than upon the roundabout or circumferential. To pull a boiler apart in the direction of its length there is the pressure per square inch multiplied by the number of square inches in the head. To resist this pull there is the entire circumference of the sheet. Area of head = .7854 D^2, while the circumference = 3.1416 D. Each roundabout seam resists a pull in proportion to diameter /4, while each longitudinal seam resists in proportion to diameter /2. Hence any stress in a longitudinal seam is twice that in a roundabout seam.

On Longitudinal Joints, the distance from center to center of the rivet holes to the edge of the plates, excepting rivet holes in the ends of Butt Straps, shall not be less than $1\frac{1}{2}$, and not more than $1\frac{3}{4}$ times the diam-

eter of the rivet holes—this distance to be measured from the center of the rivet holes to the calking edge of the plate before calking. The plate shall be beveled to an angle not sharper than 70°, to the plane of the plate, and as near to this angle as practical.

The riveted longitudinal joints of a shell or drum which exceeds 36″, in diameter, shall be a Butt and Double Strap Construction.

The longitudinal joints of a shell or drum that does not exceed 36″ in diameter may be Lap Riveted in Construction, but the maximum allowable working pressure shall not exceed 100 pounds.

The longitudinal joints of a horizontal return tubular boiler shall be located above the fire line of the setting.

The longitudinal joint of a dome 24″ or over in diameter shall be of Butt and Double Strap construction. With a maximum allowable working pressure of over 100 pounds, the flange shall be double riveted to the boiler shell.

The longitudinal joint of a dome less than 24″ in diameter may be of the Lap type, and the flange may be single riveted to the Boiler shell, provided the maximum allowable working pressure on such a dome is computed with a factor of safety of not less than 8.

In circumferential joints in horizontal return tubular boilers, exposed to the products of combustion, the shearing strength of the rivets shall not be less than 50% of the full strength of the plate corresponding to the thickness at the joint.

The distance between the center lines of any two adjacent rows of rivets, called the Back Pitch, measured at right angles to the direction of the joint, shall have the following minimum values.

"a." if P/d is 4 or less, the minimum shall be 2 d.

"b." if P/d is over 4, the minimum shall be 2 d + 0.1 (P — 4 d).

Where: P. = Pitch of the rivets in the outer row, with the rivet in the inner row coming midway between two rivets in the outer row, inches.

P. = Pitch of the rivets in the outer row less pitch of the rivets in the inner row where two rivets in the inner row come between two rivets in the outer row, inches.

d. = Diameter of the rivet hole, in inches.

The Boiler Code specifies the following factors of safety:

Factor of Safety for New Boilers.....................5

Factor of Safety for Old Boilers.....................4

The strength of rivets in shear on either side of a manhole frame or reinforcement shall be at least equal to the tensile strength of the maximum amount of shell plate removed by the opening and rivet holes for the reinforcement.

The shearing and crushing strength of rivets used for attaching lugs or brackets for the support of a boiler of any type, shall not exceed 8% of 44000 pounds per square inch for single shear, or of 88000 pounds per square inch for double shear, or of 95000 pounds per square inch for crushing.

The Supporting Lugs shall be designed so that the distance girthwise of the boiler, from the centers of the bottom rivets to the centers of the top rivets, attaching the lugs, shall not be less than 12 inches. Not more than two rivets shall come in the same longitudinal line on each lug.

DRILLING OF HOLES, PREPARATION OF WORK, DRIVING RIVETS

All rivet holes shall be drilled full size, or they may be punched not to exceed $\frac{1}{4}$ inch less than full diameter for material over 5/16 inch thickness, and $\frac{1}{8}$ inch less than full diameter for material not exceeding 5/16 inch in thickness, and then drilled or reamed to full diameter. Plates, Butt Straps, Braces, Heads, etc., shall be firmly belted together by tack bolts for drilling or reaming all rivet holes in assembled boiler plate. The tack bolt holes will be reamed after riveting has progressed.

After the drilling or reaming of the rivet holes in position the plates and Butt straps shall be separated, the burrs and chips all removed, and then the plates and Butt straps reassembled, metal to metal with barrel pins fitting the holes, and with tack bolts.

RIVETS SHALL BE OF SUFFICIENT LENGTH TO COMPLETELY FILL THE HOLES AND SHALL FORM HEADS AT LEAST AS STRONG AS THE BODIES OF THE RIVETS

Rivets shall be machine driven whenever possible, and with sufficient pressure to insure tight rivets and good heads. The pressure must be sufficient to fill the rivet holes, and shall be allowed to remain on the rivet until they have partially cooled and shrunk. A rivet shall be driven each side of a tack bolt before the tack bolt is removed.

In low pressure steam boilers for heating purposes in buildings it shall not be necessary to water jacket the rivets in the fire box where one end of each rivet is exposed to the fire or the direct radiant heat from the fire, provided any one of the following conditions is fulfilled:

a. Where the ends of the rivets away from the fire are protected by means of natural drafts of cold air induced in the regular operation of the boiler.

b. Where the ends of the rivets away from the fire are in the open air.

c. Where the rivets are protected by the usual charge of fresh fuel which is not burned in contact with the rivets.

NOTES ON BOILER JOINTS

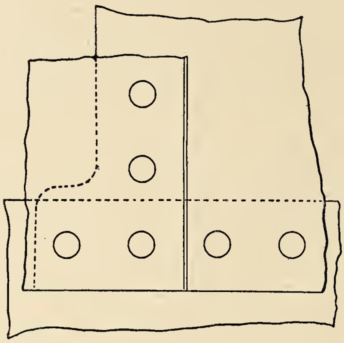
When shell plates are in excess of 9/16 inches in thickness in horizontal return tubular boilers, the portion of the plates forming the laps on the circumferential joints, where exposed to the fire or the products of combustion shall be planed or milled down to half inch thickness, provided the circumferential joint is designed with rivets whose shearing strength is not less than 50% of the full strength of the plate corresponding to the thickness of the joint, and having a strength equal to 50% of that required for longitudinal joints of the same structure.

Junction of Two Plates

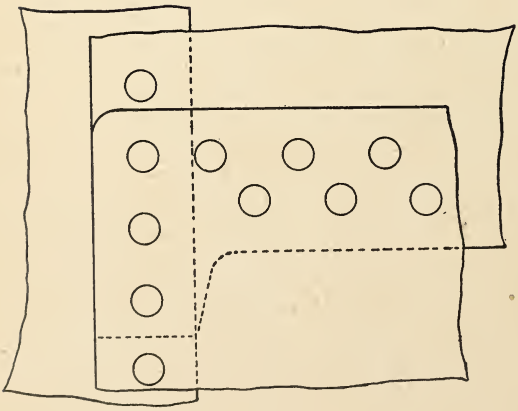
Described fully in Chapter IV.

Junction of Three Plates.

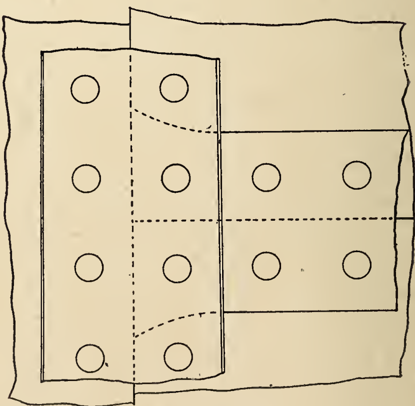
In boiler work where the riveted seams must be watertight a difficulty arises where the Cross joints meet, as here three plates overlap. One or more of the plates are thinned out by forging so that the joint may be solid. Cut 36 illustrates this condition, showing three plates overlapping and single riveted. Cut 37 illustrates a longitudinal seam double riveted, and a cross seam single riveted. Cut 38 illustrates the junction of three plates with a Butt strap, the longitudinal Butt strap being planed down and placed under the Cross Butt strap.



Cut 36.



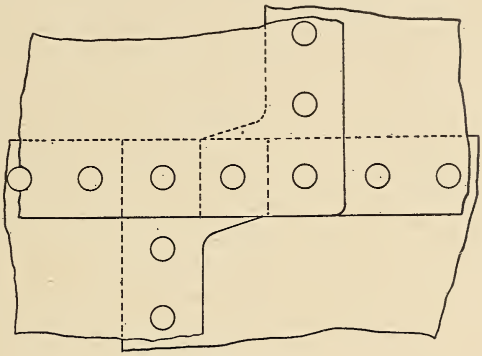
Cut 37.



Cut 38.

Junction of Four Plates

Cut 39 illustrates the overlapping of four plates. Each of the two interior plates are thinned down at the junction, and forged out so that they may be gripped each by an additional rivet in the thinned out parts.



Cut 39.

Corner connections, fire box connections, etc., are made by the use of angles, zees, etc., or by the flanging of the plate. Tees are used for stiffeners in some cases. In flanged connections previous rules should be adhered to, and the lap should never be less than three diameters of the rivet, for single riveting. For parallel connections zees, channels, double angles, etc., are used.

Maximum Allowable Working Pressure

According to the Boiler Code Rules the maximum allowable working pressure on the shell of a boiler or drum will be determined by the strength of the weakest course, computed as given previously, namely, by the thickness of the plate and the tensile strength as stamped thereon, the efficiency of the longitudinal joint, the inside diameter of the course, and the factor of safety.

$$\text{Maximum Allowable Working Pressure} = \frac{TS \times t \times E.}{R \times FS.}$$

Where: TS = Ultimate tensile strength of plate material as stamped on the plate in pounds per square inch.

t = Minimum thickness of the shell plates in the weakest course in inches.

E = Efficiency of the longitudinal joint.

R = Inside radius of the weakest course of the shell or drum in inches.

FS = Factor of Safety. For new construction = 5.

In old boilers a Lap Seam crack is common, and a typical crack found in lap seams running parallel to the longitudinal joint, located either between the rivets or adjacent to the rivet holes. When such a joint crack is found discontinue the use of the BOILER IMMEDIATELY.

In the case of a loose rivet in a boiler in service, next time the boiler is shut down, cut out the loose rivet, ream out the hole and insert a rivet of the next largest size than was formerly in place.

Overheating of the plate might be responsible for a loose rivet as described.

The Mechanical departments of the various Steam Boiler Inspection Bureaus and Companies are largely governed by the rules as established by the A. S. M. E. Boiler Code. Illustrative of this situation the Hartford Steam Boiler Inspection & Insurance Company do not issue rules governing detail of construction, but are guided in their practice by this Boiler Code.

CHAPTER VII

STRUCTURAL BUILDING WORK

It would seem at first sight that STRUCTURAL REQUIREMENTS FOR BUILDINGS would have been standardized similar to the manner in which Boiler construction has through the adoption of the Boiler Code. It is, however, very doubtful if Structural work in this country is ever standardized, in that there will be one general requirement for all building construction undertaken. It is true that in Europe there has been more or less of a working agreement between Construction Engineers and the Steel makers, and we probably could gain somewhat if more cooperation existed in this country. The large number of structural shapes found in the hand books and shape books of the various steel makers seem confusing, but it should be remembered that these mills have fixed equipment in the way of rolls, etc., for making the shapes that they tender to the engineer, and naturally they exploit these shapes that they recommend for a given purpose. It would not be possible to limit the weight of beams, channels, etc., to possibly two weights per section, under existing commercial activity in this country. Due consideration must also be given to the nature of the average American in that he has his own ideas and is going to use them. This applies to the Architect, Construction Engineer and to the Steel maker. The City governments all have their Building laws, and the subject of making uniform Building Laws for the entire country would be a vastly larger undertaking than that of the compilation of the Boiler Code.

The weight of Structural steel in a building is a difficult thing to estimate without detailed plans, and it also is evident that the incorporation of novel ideas representing the engineers personality tends to make this calculation more involved. The weight naturally will depend on the design, the number of stories, the live and dead load to be carried per square foot of floor, the weight of the facing, and the allowable unit stresses in the steel. Our Building Laws, show reasonably close similarity for all our larger cities.

The following formula is a reliable one formulated from observations, and gives the approximate weight of steel required for the steel skeleton of the average office building, whose walls are carried on structural steel work.

$$W = N \times F\,(15 + 7/10\,N).$$

Where: W = Total weight of the structural work required in pounds.

N = The number of floors, counting the roof as a floor.

F = The number of square feet in each floor.

$N \times F \times 15$ gives the weight of beams and fittings required.

$N \times F \times 7/10\,N$ gives the weight of the columns required.

The selection of Sections in structural work designing is largely a matter of judgment and should be done only by those familiar with the sections obtainable, and these sections should be limited in number to the fewest possible to accomplish desired results.

Much preliminary fabrication is obtainable from the Steel mills direct, as there are Structural shops connected with the larger of the Plate and Shape Rolling mills. It is well to know the preliminary operations conducted on fabricating and fitting of structural elements.

In the first fabrication the beams, channels, tees, angles, etc., are laid out to templates or to drawings or to both. This sequence of operation then follows:

1. Punched in the web, one or more sizes of holes.
2. Punched in the flanges, one or more sizes of holes.
3. Coped on one or both ends after punching.
4. Riveted with connecting angles on one or both ends.
5. Riveted into girders with one or more cover plates.
6. Bent or forged to shape.
7. Columns built up, all inaccessable parts after riveting being carefully painted with red lead prior to riveting.

In order to avoid unnecessary work, and to obtain quick delivery the designer should observe the following:

1. Specifications where possible should specify but one size rivet hole to avoid two operations and placements in punching.
2. Avoid coping by setting the Floor beams sufficiently below the top flanges of the main girder, providing the girder is of sufficient depth.
3. Avoid built up or box girders, using beams of greater depth.
4. Avoid bending, welding, etc., by the proper design of riveted members.

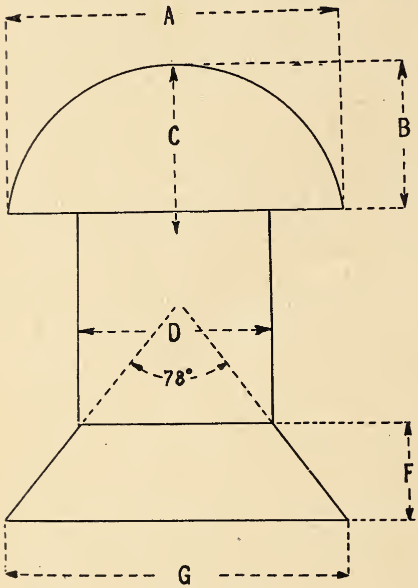
The grade of metal entering into the manufacture of structural plate, shapes, and rivets is largely standardized, the specifications of the A.A.S.M., and of the A.S.T.M. being accepted almost universally. Following is a tabulation of the requirements in this respect.

Specification	A.A.S.M. Class B.	A.S.T.M.	A.S.T.M.
For. Steel for:	Buildings and Structures	Structural Buildings	Structural Nickel Steel
Chemical requirements:			
Carbon	....	....	not over .45
Manganese	....	....	" .70
Phosphorous Bess	not over 0.100	not over 0.100	" ....
Acid	" 0.080	....	" .050
Basic	" 0.060	" 0.060	" .040
Sulphur	....	....	" .050
Nickel	....	....	not under 3.250
Physical requirements:			
Tensile strength lbs. sq. in.	55/65000.	55/65000.	85000 to 100000.
Yield point, lbs. sq. in.	½ TS.	½ TS.	50000.
Elongation in 8″ % min.	1400000 ÷ TS.	1400000 ÷ TS.	1500000 ÷ TS.
Elongation in 2″ % min.	22%	22%	....
Reduction area, %	....	....	25%
For Rivets:	Class C. Rivets	Rivets	Rivets
Chemical requirements:			
Carbon	....	....	not over .30
Manganese	....	....	" .60
Phosphorous Basic OH	not over 0.040	not over 0.060	" .030
Acid	" 0.040	....	" .040
Sulphur	" 0.050	" 0.045	" .045
Nickel	....	....	over 3.25
Physical requirements:			
Tensile strength, lbs. sq. in	46/56000.	45/56000.	70000 to 80000.
Yield point, lb.s. sq. in.	½ TS.	½ TS.	45000.
Elongation in 8″ %	1400000 ÷ TS.	1400000 ÷ TS.	1500000 ÷ TS.
Reduction area	....	....	40%
Cold Bend	180° Flat	180° Flat	180° Flat

STANDARD HEADS FOR STRUCTURAL RIVETS

The Severance Manufacturing Company make standard Structural rivets to the dimensions shown on Cut 42. Some large consumers of structural rivets have standard dimensions of their own, the variation from our standard being however slight. For general information we illustrate the Standards of the American Bridge Company, and of the Cambria Steel Company for Structural Rivet heads. These are given in Cuts 40 and 41 respectively.

SEVERANCE MANUFACTURING COMPANY
STANDARD STRUCTURAL RIVET



Button Head:

Diameter of Rivet $= d.$

Diameter head $= a = 1\frac{3}{4}\,d.$

Height head $= b = \frac{3}{4}d.$

Radius $= c.$

Countersunk Head:

Height $= f = \frac{1}{2}\,d.$

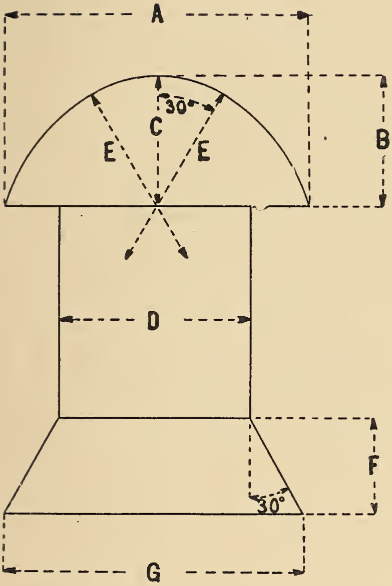
Width $= g = 1.84\,d$

Taper $= 78°.$

Cut 42.

The following dimensions are Standard for Structural Rivets:

Diam. of Rivet "d."	BUTTON HEAD		COUNTERSUNK HEAD	
	Height "b."	Diameter "a."	Height "f."	Width "g."
$\frac{1}{2}''$	$\frac{3}{8}''$	$\frac{7}{8}''$	$\frac{1}{4}''$	$\frac{15}{16}''$
$\frac{9}{16}''$	$\frac{27}{64}''$	$\frac{63}{64}''$	$\frac{9}{32}''$	$1\frac{1}{32}''$
$\frac{5}{8}''$	$\frac{15}{32}''$	$1\frac{3}{32}''$	$\frac{5}{16}''$	$1\frac{5}{32}''$
$\frac{11}{16}''$	$\frac{33}{64}''$	$1\frac{13}{64}''$	$\frac{11}{32}''$	$1\frac{17}{64}''$
$\frac{3}{4}''$	$\frac{9}{16}''$	$1\frac{5}{16}''$	$\frac{3}{8}''$	$1\frac{3}{8}''$
$\frac{13}{16}''$	$\frac{39}{64}''$	$1\frac{27}{64}''$	$\frac{13}{32}''$	$1\frac{1}{2}''$
$\frac{7}{8}''$	$\frac{21}{32}''$	$1\frac{17}{32}''$	$\frac{7}{16}''$	$1\frac{19}{32}''$
$\frac{15}{16}''$	$\frac{45}{64}''$	$1\frac{41}{64}''$	$\frac{15}{32}''$	$1\frac{23}{32}''$
$1''$	$\frac{3}{4}''$	$1\frac{3}{4}''$	$\frac{1}{2}''$	$1\frac{27}{32}''$
$1\frac{1}{16}''$	$\frac{51}{64}''$	$1\frac{55}{64}''$	$\frac{17}{32}''$	$1\frac{61}{64}''$
$1\frac{1}{8}''$	$\frac{27}{32}''$	$1\frac{31}{32}''$	$\frac{9}{16}''$	$2\frac{1}{16}''$
$1\frac{3}{16}''$	$\frac{57}{64}''$	$2\frac{5}{64}''$	$\frac{19}{32}''$	$2\frac{3}{16}''$
$1\frac{1}{4}''$	$\frac{15}{16}''$	$2\frac{3}{16}''$	$\frac{5}{8}''$	$2\frac{19}{64}''$
$1\frac{3}{8}''$	$1\frac{1}{32}''$	$2\frac{13}{32}''$	$\frac{11}{16}''$	$2\frac{17}{32}''$
$1\frac{1}{2}''$	$1\frac{1}{8}''$	$2\frac{5}{8}''$	$\frac{3}{4}''$	$2\frac{3}{4}''$



Cut 40.

AMERICAN BRIDGE COMPANY STANDARD.

Proportions of Rivets.

Full Driven Head:

Diameter $= a = 1.5\ d + \frac{1}{8}''$.

Depth $= b = 0.425\ a$.

Radius $= c = b$.

Radius $= e = 1.5\ b$.

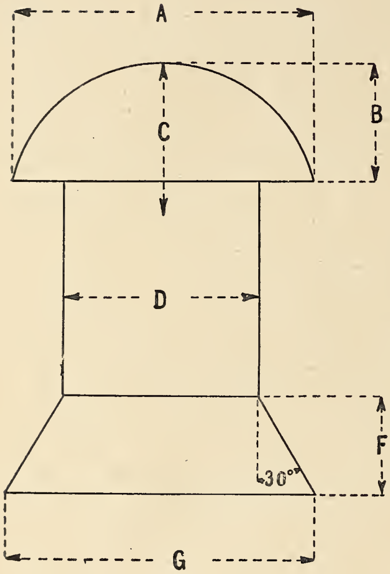
Countersunk Head:

Depth $= f = 0.5\ d$.

Diameter $= g = 1.577\ d$.

Using the above formulae we get the following dimensions:

Diameter of Rivet "d."	a	b	c	e	f	g
$\frac{3}{8}''$	$\frac{11}{16}''$	$\frac{19}{64}''$	$\frac{19}{64}''$	$\frac{7}{16}''$	$\frac{3}{16}''$	$\frac{19}{32}''$
$\frac{1}{2}''$	$\frac{7}{8}''$	$\frac{3}{8}''$	$\frac{3}{8}''$	$\frac{9}{16}''$	$\frac{1}{4}''$	$\frac{25}{32}''$
$\frac{5}{8}''$	$1\frac{1}{16}''$	$\frac{29}{64}''$	$\frac{29}{64}''$	$\frac{43}{64}''$	$\frac{5}{16}''$	$1''$
$\frac{3}{4}''$	$1\frac{1}{4}''$	$\frac{17}{32}''$	$\frac{17}{32}''$	$\frac{51}{64}''$	$\frac{3}{8}''$	$1\frac{3}{16}''$
$\frac{7}{8}''$	$1\frac{7}{16}''$	$\frac{39}{64}''$	$\frac{39}{64}''$	$\frac{59}{64}''$	$\frac{7}{16}''$	$1\frac{3}{8}''$
$1''$	$1\frac{5}{8}''$	$\frac{11}{16}''$	$\frac{11}{16}''$	$1\frac{1}{32}''$	$\frac{1}{2}''$	$1\frac{9}{16}''$
$1\frac{1}{8}''$	$1\frac{13}{16}''$	$\frac{49}{64}''$	$\frac{49}{64}''$	$1\frac{5}{32}''$	$\frac{9}{16}''$	$1\frac{3}{4}''$
$1\frac{1}{4}''$	$2''$	$\frac{27}{32}''$	$\frac{27}{32}''$	$1\frac{1}{4}''$	$\frac{5}{8}''$	$1\frac{15}{16}''$



Cut 41.

CAMBRIA STEEL COMPANY STANDARD.

Proportions of Heads.

Button Head:

Diameter = a = ...

Height = b = 6/10 × d.

Radius = e = $\frac{3}{4}$ d + 1/16″.

Countersunk Head:

Depth = f = ...

Diameter = g = same as a.

Angle of Countersunk = 30°.

Using the above formulae we get the following dimensions:

Diameter of Rivet "d."	a	b	c	f	g
$\frac{1}{4}''$	$\frac{15}{32}''$	.150″	$\frac{1}{4}''$	$\frac{3}{16}''$	$\frac{15}{32}''$
$\frac{3}{8}''$	$\frac{21}{32}''$	.225″	$\frac{11}{32}''$	$\frac{7}{32}''$	$\frac{21}{32}''$
$\frac{1}{2}''$	$\frac{27}{32}''$	.300″	$\frac{7}{16}''$	$\frac{9}{32}''$	$\frac{27}{32}''$
$\frac{5}{8}''$	$1\frac{1}{32}''$	.375″	$\frac{17}{32}''$	$\frac{11}{32}''$	$1\frac{1}{32}''$
$\frac{3}{4}''$	$1\frac{7}{32}''$	.450″	$\frac{5}{8}''$	$\frac{3}{8}''$	$1\frac{7}{32}''$
$\frac{7}{8}''$	$1\frac{3}{8}''$	.525″	$\frac{23}{32}''$	$\frac{7}{16}''$	$1\frac{3}{8}''$
1″	$1\frac{9}{16}''$	.600″	$\frac{13}{16}''$	$\frac{1}{2}''$	$1\frac{9}{16}''$
$1\frac{1}{8}''$	$1\frac{3}{4}''$	.675″	$\frac{29}{32}''$	$\frac{17}{32}''$	$1\frac{3}{4}''$

In figuring clearances for Rivet Heads allow for heights as follows: $\frac{5}{8}''$ for $\frac{3}{4}''$ Rivets. $\frac{3}{4}''$ for $\frac{7}{8}''$ Rivets.

On account of the mass of detail figuring necessary in structural members design, numerous tables are used. This catalogue is devoted as far as possible to the subject of rivets. We accordingly give the following table for the weight of Structural rivets per 100, these rivets being the Standard Button Headed type.

Approximate Weights of Rivets per 100, in Pounds

Length Under Head	DIAMETERS					
	⅛	3-16	¼	5-16	⅜	7-16
½	.58	.6	1.3	1.9	3.5	5.7
⅝	.64	.7	1.5	2.2	3.9	6.2
¾	.70	.8	1.7	2.4	4.3	6.7
⅞	.76	.9	1.8	2.7	4.6	7.3
1	.82	1.0	2.0	2.9	5.0	7.8
1⅛	.88	1.1	2.1	3.2	5.4	8.3
1¼	.94	1.2	2.3	3.5	5.8	8.9
1⅜	1.00	1.3	2.5	3.7	6.1	9.4
1½	1.06	1.4	2.6	4.0	6.5	9.9
1⅝	1.12	1.5	2.8	4.2	6.9	10.5
1¾	1.18	1.6	2.9	4.5	7.3	11.
1⅞	1.24	1.7	3.1	4.8	7.6	11.5
2	1.30	1.8	3.3	5.0	8.0	12.
2⅛	....	1.9	3.4	5.3	8.4	12.6
2¼	....	2.0	3.6	5.5	8.8	13.1
2⅜	....	2.1	3.7	5.8	9.1	13.6
2½	....	2.2	3.9	6.1	9.5	14.2
2⅝	....	2.3	4.1	6.3	9.9	14.7
2¾	....	2.4	4.2	6.6	10.3	15.2
2⅞	....	2.5	4.4	6.8	10.6	15.8
3	....	2,6	4.5	7.1	11.	16.3
3¼	....	2.8	4.9	7.6	11.8	17.3
3½	....	3.0	5.2	8.1	12.5	18.4
3¾	....	3.2	5.5	8.7	13.3	19.5
4	....	3.4	5.8	9.2	14.	20.5
4¼	....	3.6	6.1	9.7	14.8	21.6
4½	....	3.8	6.5	10.2	15.5	22.6
4¾	....	4.0	6.8	10.7	16.3	23.7
5	....	4.1	7.1	11.3	17.	24.8
5¼	....	4.3	7.4	11.8	17.8	25.8
5½	....	4.5	7.7	12.3	18.5	26.9
5¾	....	4.7	8.1	12.9	19.3	27.9
6	....	4.9	8.4	13.3	20.	29.
6¼	....	5.1	8.7	13.9	20.8	30.1
6½	....	5.3	9.0	14.4	21.5	31.1
6¾	....	5.5	9.3	14.9	22.3	32.2
7	....	5.7	9.7	15.4	23.	33.2

STRUCTURAL RIVETS

Weight in Pounds per 100 Rivets with Button Heads. Calculations Made from Actual Specimens

Length Under Head Inches	DIAMETER OF RIVETS, INCHES						
	1-2	9-16	5-8	11-16	3-4	13-16	7-8
½	7.19	9.84	13.18	16.64	21.55	26.52	30.35
⅝	7.88	10.67	14.26	17.91	23.09	28.31	32.40
¾	8.58	11.51	15.34	19.19	24.63	30.10	34.45
⅞	9.27	12.34	16.41	20.46	26.16	31.89	36.50
1	9.96	13.17	17.49	21.74	27.70	33.68	38.55
⅛	10.65	14.00	18.57	23.02	29.24	35.48	40.60
¼	11.35	14.84	19.65	24.29	30.78	37.27	42.65
⅜	12.04	15.67	20.72	25.57	32.31	39.06	44.70
½	12.73	16.50	21.80	26.85	33.85	40.85	46.75
⅝	13.42	17.33	22.88	28.12	35.39	42.64	48.80
¾	14.12	18.17	23.96	29.40	36.93	44.43	50.85
⅞	14.81	19.00	25.03	30.67	38.46	46.22	52.90
2	15.50	19.83	26.11	31.95	40.00	48.01	54.95
⅛	16.19	20.66	27.19	33.23	41.54	49.80	57.00
¼	16.89	21.50	28.27	34.50	43.08	51.59	59.05
⅜	17.58	22.33	29.34	35.78	44.61	53.39	61.10
½	18.27	23.16	30.42	37.06	46.15	55.18	63.15
⅝	18.96	23.99	31.50	38.33	47.69	56.97	65.20
¾	19.66	24.83	32.58	39.61	49.23	58.76	67.25
⅞	20.35	25.66	33.65	40.88	50.76	60.55	69.30
3	21.04	26.49	34.73	42.16	52.30	62.34	71.35
⅛	21.73	27.32	35.81	43.44	53.84	64.13	73.40
¼	22.43	28.16	36.89	44.71	55.38	65.92	75.45
⅜	23.12	28.99	37.96	45.99	56.91	67.71	77.50
½	23.81	29.82	39.04	47.27	58.45	69.50	79.55
⅝	24.50	30.65	40.12	48.54	59.99	71.30	81.60
¾	25.20	31.49	41.20	49.82	61.53	73.09	83.65
⅞	25.89	32.32	42.27	51.09	63.06	74.88	85.70
4	26.58	33.15	43.35	52.37	64.60	76.67	87.75
⅛	27.27	33.98	44.43	53.65	66.14	78.46	89.80
¼	27.97	34.82	45.51	54.92	67.68	80.25	91.85
⅜	28.66	35.65	46.58	56.20	69.21	82.04	93.90
½	29.35	36.48	47.66	57.48	70.75	83.83	95.95
⅝	30.04	37.31	48.74	58.75	72.29	85.62	98.00
¾	30.74	38.15	49.82	60.03	73.83	87.41	100.05
⅞	31.43	38.98	50.89	61.31	75.36	89.21	102.10
5	32.12	39.81	51.97	62.58	76.90	91.00	104.15
⅛	32.81	40.64	53.05	63.83	78.44	92.79	106.20
¼	33.51	41.48	54.13	65.13	79.98	94.58	108.25
⅜	34.20	42.31	55.20	66.41	81.51	96.37	110.30
½	34.89	43.14	56.28	67.69	83.05	98.16	112.35
⅝	35.58	43.97	57.36	68.96	84.59	99.95	114.40
¾	36.28	44.81	58.44	70.24	86.13	101.74	116.45
⅞	36.97	45.64	59.51	71.51	87.66	103.53	118.50
6	37.66	46.47	60.59	72.79	89.20	105.32	120.55
⅛	38.35	47.30	61.67	74.07	90.74	107.12	122.60
¼	39.05	48.14	62.75	75.34	92.28	108.91	124.65
⅜	39.74	48.97	63.82	76.62	93.81	110.70	126.70
½	40.43	49.80	64.90	77.89	95.35	112.49	128.75
⅝	41.12	50.63	65.98	79.17	96.89	114.28	130.80
¾	41.82	51.47	67.06	80.45	98.43	116.07	132.85
⅞	42.51	52.30	68.13	81.72	99.96	117.86	134.90
7	43.20	53.13	69.21	83.00	101.50	119.65	136.95
⅛	43.89	53.96	70.29	84.28	103.04	121.44	139.00
¼	44.59	54.80	71.37	85.55	104.58	123.23	141.05
⅜	45.28	55.63	72.44	86.83	106.11	125.03	143.10
½	45.97	56.46	73.52	88.11	107.65	126.82	145.15
⅝	46.66	57.29	74.60	89.38	109.19	128.61	147.20
¾	47.36	58.13	75.68	90.66	110.73	130.40	149.25
⅞	48.05	58.96	76.75	91.93	112.26	132.19	151.30

STRUCTURAL RIVETS—WEIGHT IN POUNDS—Continued

Length Under Head Inches	DIAMETER OF RIVETS, INCHES						
	1-2	9-16	5-8	11-16	3-4	13-16	7-8
8	48.74	59.79	77.83	93.21	113.80	133.98	153.35
⅛	49.43	60.62	78.91	94.49	115.34	135.77	155.40
¼	50.13	61.46	79.99	95.76	116.88	137.56	157.45
⅜	50.82	62.29	81.06	97.04	118.41	139.35	159.50
½	51.51	63.12	82.14	98.32	119.95	141.14	161.55
⅝	52.20	63.95	83.22	99.59	121.49	142.94	163.60
¾	52.90	64.79	84.30	100.87	123.03	144.73	165.65
⅞	53.59	65.62	85.37	102.14	124.56	146.52	167.70
9	54.28	66.45	86.45	103.42	126.10	148.31	169.75
⅛	54.97	67.28	87.53	104.70	127.64	150.10	171.80
¼	55.67	68.12	88.61	105.97	129.18	151.89	173.85
⅜	56.36	68.95	89.68	107.25	130.71	153.68	175.90
½	57.05	69.78	90.76	108.53	132.25	155.47	177.95
⅝	57.74	70.61	91.84	109.80	133.79	157.26	180.00
¾	58.44	71.45	92.92	111.08	135.33	159.05	182.05
⅞	59.13	72.28	93.99	112.35	136.86	160.85	184.10
10	59.82	73.11	95.07	113.63	138.40	162.64	186.15
⅛	60.51	73.94	96.15	114.91	139.94	164.43	188.20
¼	61.21	74.78	97.23	116.18	141.48	166.22	190.25
⅜	61.90	75.61	98.30	117.46	143.01	168.01	192.30
½	62.59	76.44	99.38	118.74	144.55	169.80	194.35
⅝	63.28	77.27	100.46	120.01	146.09	171.59	196.40
¾	63.98	78.11	101.54	121.29	147.63	173.38	198.45
⅞	64.67	78.94	102.61	122.59	149.16	175.17	200.50
11	65.36	79.77	103.69	123.84	150.70	176.96	202.55
⅛	66.05	80.60	104.77	125.12	152.24	178.76	204.60
¼	66.75	81.44	105.85	126.39	153.78	180.55	206.65
⅜	67.44	82.27	106.92	127.67	155.31	182.34	208.70
½	68.13	83.10	108.00	128.95	156.85	184.13	210.75
⅝	68.82	83.93	109.08	130.22	158.39	185.92	212.80
¾	69.52	84.77	110.16	131.50	159.93	187.71	214.85
⅞	70.21	85.60	111.23	132.77	161.46	189.50	216.90
12	70.90	86.43	112.31	134.05	163.00	191.30	218.95
⅛	71.59	87.26	113.39	135.32	164.54	193.08	221.00
¼	72.29	88.10	114.47	136.60	166.08	194.87	223.05
⅜	72.98	88.93	115.54	137.88	167.61	196.67	225.10
½	73.67	89.76	116.62	139.16	169.15	198.46	227.15
⅝	74.36	90.59	117.70	140.43	170.69	200.25	229.20
¾	75.06	91.43	118.78	141.71	172.23	202.04	231.25
⅞	75.75	92.26	119.85	142.98	173.76	203.83	233.30
13	76.44	93.09	120.93	144.26	175.30	205.62	235.35
⅛	77.13	93.92	122.01	145.54	176.84	207.41	237.40
¼	77.83	94.76	123.09	146.81	178.38	209.20	239.45
⅜	78.52	95.59	124.16	148.09	179.91	210.99	241.50
½	79.21	96.42	125.24	149.37	181.45	212.78	243.55
⅝	79.90	97.25	126.32	150.64	182.99	214.58	245.60
¾	80.60	98.09	127.40	151.92	184.53	216.37	247.65
⅞	81.29	98.92	128.47	153.19	186.06	218.16	249.70
14	81.98	99.75	129.55	154.47	187.60	219.95	251.75
⅛	82.67	100.58	130.63	155.75	189.14	221.74	253.80
¼	83.37	101.42	131.71	157.02	190.68	223.53	255.85
⅜	84.06	102.25	132.78	158.30	192.21	225.32	257.90
½	84.75	103.08	133.86	159.58	193.75	227.11	259.95
⅝	85.44	103.91	134.94	160.85	195.29	228.90	262.00
¾	86.14	104.75	136.02	162.13	196.83	230.69	264.05
⅞	86.83	105.58	137.09	163.41	198.36	232.49	266.10
15	87.52	106.41	138.17	164.68	199.90	234.27	268.15
Weight of 100 Heads							
Button	4.42	6.51	8.87	11.53	15.40	19.35	22.15
Cone	5.04		9.83	13.08	16.55	20.24	24.50
Steeple	4.82		10.08		14.19	19.12	22.58
Countersunk	2.82		5.22		10.09		15.45
Weight of 100 Shanks 1-in. long	5.54	6.66	8.62	10.21	12.30	14.33	16.40

STRUCTURAL RIVETS—WEIGHT IN POUNDS—Continued

Length Under Head Inches	DIAMETER OF RIVET, INCHES					
	15-16	1	1 1-16	1 1-8	1 3-16	1 1-4
½	37.50	43.83	51.57			
⅝	39.84	46.46	54.58			
¾	42.18	49.10	57.59			
⅞	44.52	51.73	60.59			
1	46.86	54.36	63.60	71.94	86.71	99.20
⅛	49.20	56.99	66.60	75.32	90.49	103.37
¼	51.54	59.63	69.61	78.70	94.27	107.54
⅜	53.88	62.26	72.62	82.08	98.05	111.72
½	56.22	64.89	75.62	85.46	101.83	115.89
⅝	58.56	67.53	78.63	88.84	105.61	120.07
¾	60.90	70.16	81.63	92.22	109.39	124.24
⅞	63.24	72.79	84.64	95.60	113.17	128.41
2	65.58	75.42	87.65	98.98	116.95	132.59
⅛	67.92	78.06	90.65	102.36	120.73	136.76
¼	70.26	80.69	93.66	105.74	124.51	140.94
⅜	72.60	83.32	96.66	109.12	128.29	145.11
½	74.94	85.96	99.67	112.50	132.07	149.28
⅝	77.28	88.59	102.68	115.88	135.85	153.46
¾	79.62	91.22	105.68	119.26	139.63	157.63
⅞	81.96	93.86	108.69	122.64	143.41	161.81
3	84.30	96.49	111.69	126.02	147.20	165.98
⅛	86.64	99.12	114.70	129.39	150.98	170.15
¼	88.98	101.75	117.70	132.77	154.76	174.33
⅜	91.32	104.39	120.71	136.15	158.54	178.50
½	93.66	107.02	123.72	139.53	162.32	182.68
⅝	96.00	109.65	126.72	142.91	166.10	186.85
¾	98.34	112.29	129.73	146.29	169.88	191.03
⅞	100.68	114.92	132.73	149.67	173.66	195.20
4	103.02	117.55	135.74	153.05	177.44	199.37
⅛	105.36	120.19	138.74	156.43	181.22	203.55
¼	107.70	122.82	141.75	159.81	185.00	207.72
⅜	110.04	125.45	144.75	163.19	188.78	211.90
½	112.38	128.08	147.76	166.57	192.56	216.07
⅝	114.72	130.72	150.77	169.95	196.34	220.24
¾	117.06	133.35	153.77	173.33	200.12	224.42
⅞	119.40	135.98	156.78	176.71	203.90	228.59
5	121.72	138.62	159.78	180.09	207.68	232.77
⅛	124.06	141.25	162.79	183.47	211.46	236.94
¼	126.42	143.88	165.80	186.85	215.25	241.11
⅜	128.72	146.51	168.80	190.23	219.03	245.29
½	131.10	149.15	171.81	193.61	222.81	249.46
⅝	133.44	151.78	174.81	196.98	226.59	253.64
¾	135.78	154.41	177.82	200.36	230.37	257.81
⅞	138.12	157.05	180.83	203.74	234.15	261.98
6	140.46	159.68	183.83	207.12	237.93	266.16
⅛	142.80	162.31	186.84	210.50	241.71	270.33
¼	145.14	164.95	189.84	213.88	245.49	274.51
⅜	147.48	167.58	192.85	217.26	249.27	278.68
½	149.82	170.22	195.86	220.64	253.05	282.85
⅝	152.16	172.85	198.86	224.02	256.83	287.03
¾	154.50	175.48	201.87	227.40	260.61	291.20
⅞	156.84	178.12	204.87	230.80	264.39	295.38
7	159.18	180.75	207.88	234.16	268.17	299.55
⅛	161.52	183.38	210.88	237.54	271.95	303.72
¼	163.86	186.01	213.89	240.92	275.74	307.90
⅜	166.20	188.65	216.90	244.30	279.52	312.07
½	168.54	191.28	219.90	247.68	283.30	316.25
⅝	170.88	193.91	222.91	251.06	287.08	320.42
¾	173.22	196.55	225.91	254.44	290.86	324.59
⅞	175.56	199.18	228.92	257.82	294.64	328.77

STRUCTURAL RIVETS—WEIGHT IN POUNDS—Continued

Length Under Head Inches	DIAMETER OF RIVET, INCHES					
	15-16	1	1 1-16	1 1-8	1 3-16	1 1-4
8	177.90	201.81	231.93	261.20	298.42	332.96
⅛	180.24	204.45	234.93	264.57	302.20	337.13
¼	182.58	207.08	237.94	267.95	305.98	341.31
⅜	184.92	209.71	240.94	271.33	309.76	345.48
½	187.26	212.34	243.95	274.71	313.54	349.66
⅝	189.60	214.98	246.95	278.09	317.32	353.83
¾	191.94	217.61	249.96	281.47	321.10	358.00
⅞	194.28	220.24	252.96	284.85	324.88	362.18
9	196.59	222.88	255.97	288.23	328.66	366.35
⅛	198.93	225.51	258.98	291.61	332.44	370.53
¼	201.27	228.14	261.98	294.99	336.22	374.70
⅜	203.61	230.78	264.99	298.37	340.01	378.87
½	205.95	233.41	267.99	301.75	343.79	383.05
⅝	208.29	236.04	271.00	305.13	347.57	387.22
¾	210.63	238.67	274.01	308.51	351.35	391.40
⅞	212.97	241.31	277.01	311.89	355.13	395.57
10	215.30	243.92	280.02	315.27	358.91	399.74
⅛	217.65	246.56	283.02	318.65	362.69	403.92
¼	219.99	249.19	286.03	322.03	366.47	408.09
⅜	222.33	251.82	289.04	325.41	370.25	412.27
½	224.67	254.45	292.04	328.79	374.03	416.44
⅝	227.01	257.09	295.05	332.16	377.81	420.61
¾	229.35	259.72	298.05	335.54	381.59	424.79
⅞	231.69	262.35	301.06	338.92	385.37	428.96
11	234.03	264.98	304.07	342.30	389.15	433.14
⅛	236.37	267.62	307.07	345.68	392.93	437.31
¼	238.71	270.25	310.08	349.06	396.71	441.48
⅜	241.05	272.89	313.08	352.44	400.49	445.66
½	243.39	275.52	316.09	355.82	404.28	449.83
⅝	245.73	278.15	319.10	359.20	408.06	454.01
¾	248.07	280.78	322.10	362.58	411.84	458.15
⅞	250.41	283.42	325.11	365.96	415.62	462.35
12	252.75	286.05	328.11	369.34	419.40	466.53
⅛	255.09	288.68	331.12	372.72	423.18	470.70
¼	257.43	291.32	334.12	376.10	426.96	474.88
⅜	259.77	293.95	337.13	379.48	430.74	479.05
½	262.11	296.58	340.14	382.86	434.52	483.23
⅝	264.45	299.22	343.14	386.24	438.30	487.40
¾	266.79	301.85	346.15	389.62	442.08	491.57
⅞	269.13	304.48	349.15	393.00	445.86	495.75
13	271.47	307.11	352.16	396.38	449.64	499.92
⅛	273.81	309.75	355.17	399.79	453.42	504.10
¼	276.15	312.38	358.17	403.13	457.20	508.27
⅜	278.49	315.01	361.18	406.51	460.98	512.44
½	280.83	317.65	364.18	409.89	464.77	516.62
⅝	283.17	320.28	367.19	413.27	468.55	520.79
¾	285.51	322.91	370.20	416.65	472.33	524.97
⅞	287.85	325.55	373.20	420.03	476.11	529.14
14	290.19	328.18	376.21	423.41	479.89	533.31
⅛	292.53	330.81	379.21	426.79	483.67	537.49
¼	294.87	333.44	382.22	430.17	487.45	541.66
⅜	297.21	336.08	385.23	433.55	491.23	545.84
½	299.55	338.71	388.23	436.93	495.01	550.01
⅝	301.89	341.34	391.24	440.31	498.79	554.18
¾	304.23	343.98	394.24	443.69	502.57	558.38
⅞	306.57	346.61	397.25	447.07	506.36	562.56
15	308.88	349.23	400.25	450.45	510.14	566.73
Weight of 100 Heads						
Button	28.14	33.30	39.55	44.91	56.46	65.80
Cone	30.10	37.08	45.57	53.24	63.96	73.83
Steeple	28.97	37.19	41.27	55.03		72.09
Countersunk	19.12	22.74	27.09	30.01		42.64
Weight of 100 Shanks 1-in. long	18.72	21.06	24.05	27.04	30.25	33.40

STRUCTURAL RIVETS—WEIGHT IN POUNDS—Continued

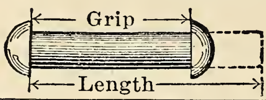
Length Under Head Inches	DIAMETER OF RIVET, INCHES 1 5-16	1 3-8	1 7-16	1 1-2	1 9-16	1 5-8
1	104.56	130.86	141.29	158.29	175.77	197.20
⅛	109.15	135.91	146.78	164.30	182.24	204.26
¼	113.74	140.95	152.28	170.30	188.71	211.31
⅜	118.33	145.99	157.77	176.31	195.17	218.37
½	122.92	151.04	163.26	182.32	201.64	225.42
⅝	127.51	156.08	168.75	188.33	208.11	232.48
¾	132.10	161.12	174.25	194.33	214.58	239.53
⅞	136.69	166.16	179.74	200.34	221.04	246.59
2	141.28	171.21	185.23	206.35	227.51	253.64
⅛	145.87	176.25	190.72	212.35	233.98	260.70
¼	150.46	181.29	196.22	218.36	240.45	267.75
⅜	155.05	186.34	201.71	224.37	246.91	274.81
½	159.64	191.38	207.20	230.38	253.38	281.86
⅝	164.23	196.42	212.69	236.38	259.85	288.92
¾	168.82	201.47	218.19	242.39	266.32	295.97
⅞	173.41	206.51	223.68	248.40	272.78	303.03
3	178.00	211.55	229.17	254.41	279.25	310.08
⅛	182.59	216.59	234.66	260.41	285.72	317.14
¼	187.18	221.64	240.16	266.42	292.19	324.19
⅜	191.77	226.68	245.65	272.43	298.65	331.25
½	196.36	231.72	251.14	278.44	305.12	338.31
⅝	200.95	236.77	256.63	284.44	311.59	345.36
¾	205.54	241.81	262.13	290.45	318.06	352.41
⅞	210.13	246.85	267.63	296.47	324.52	359.47
4	214.72	251.90	273.11	302.47	330.99	366.52
⅛	219.31	256.94	278.60	308.47	337.46	373.58
¼	223.90	261.98	284.10	314.48	343.93	380.63
⅜	228.49	267.03	289.59	320.49	350.39	387.69
½	233.08	272.07	295.08	326.50	356.86	394.74
⅝	237.67	277.11	300.57	332.50	363.33	401.80
¾	242.26	282.15	306.07	338.51	369.80	408.86
⅞	246.85	287.20	311.56	344.52	376.26	415.91
5	251.44	292.24	317.05	350.52	382.73	422.96
⅛	256.03	297.28	322.54	356.53	389.20	430.02
¼	260.62	302.33	328.04	362.54	395.67	437.07
⅜	265.21	307.37	333.53	368.55	402.13	444.13
½	269.80	312.41	339.02	374.56	408.60	451.18
⅝	274.39	317.46	344.51	380.56	415.07	458.24
¾	278.98	322.50	350.01	386.57	421.54	465.29
⅞	283.57	327.54	355.50	392.58	428.00	472.35
6	288.16	332.58	360.99	398.59	434.47	479.40
⅛	292.75	337.63	366.48	404.59	440.94	486.46
¼	297.34	342.67	371.98	410.60	447.41	493.51
⅜	301.93	347.71	377.47	416.61	453.88	500.57
½	306.52	352.76	382.96	422.61	460.34	507.62
⅝	311.11	357.80	388.45	428.62	466.81	514.68
¾	315.70	362.84	393.95	434.63	473.28	521.73
⅞	320.29	367.89	399.44	440.64	479.74	528.79
7	324.88	372.93	404.93	446.64	486.21	535.84
⅛	329.47	377.97	410.42	452.65	492.68	542.90
¼	334.06	383.01	415.92	458.66	499.15	549.95
⅜	338.65	388.06	421.41	464.67	505.61	557.01
½	343.24	393.10	426.90	470.67	512.08	564.06
⅝	347.83	398.14	432.39	476.68	518.55	571.12
¾	352.42	403.19	437.89	482.69	525.02	578.17
⅞	357.01	408.23	443.38	488.70	531.48	585.23
8	361.60	413.27	448.87	494.70	537.95	592.28
⅛	366.19	418.32	454.36	500.71	544.42	599.36
¼	370.78	423.36	459.86	506.72	550.89	606.39
⅜	375.37	428.40	465.35	512.72	557.35	613.46
½	379.96	433.44	470.84	518.73	563.82	620.50
⅝	384.55	438.49	476.33	524.74	570,29	627.56
¾	389.14	443.53	481.83	530.75	576.76	634.61
⅞	393.73	448.57	487.32	536.75	583.22	641.67

STRUCTURAL RIVETS—WEIGHT IN POUNDS—Continued

Length Under Head Inches	DIAMETER OF RIVET, INCHES					
	1 5-16	1 3-8	1 7-16	1 1-2	1 9-16	1 5-8
9	398.32	453.62	492.81	542.76	589.69	648.72
⅛	402.91	458.66	498.30	548.77	596.16	655.78
¼	407.50	463.70	503.80	554.78	602.63	662.83
⅜	412.09	468.75	509.29	560.78	609.09	669.89
½	416.68	473.79	514.78	566.79	615.56	676.94
⅝	421.27	478.83	520.27	572.80	622.03	684.00
¾	425.86	483.87	525.77	578.81	628.50	691.05
⅞	430.45	488.92	531.26	584.81	634.96	698.11
10	435.04	493.96	536.75	590.82	641.43	705.16
⅛	439.63	499.00	542.24	596.83	647.90	712.22
¼	444.22	504.05	547.74	602.84	654.37	719.27
⅜	448.81	509.09	553.23	608.84	660.83	726.33
½	453.40	514.13	558.72	614.85	667.30	733.38
⅝	457.99	519.18	564.21	620.86	673.77	740.44
¾	462.58	524.22	569.71	626.87	680.24	747.49
⅞	467.17	529.26	575.20	632.87	686.70	754.55
11	471.76	534.30	580.67	638.88	693.17	761.60
⅛	476.35	539.35	586.18	644.89	699.64	768.66
¼	480.94	544.39	591.68	650.89	706.11	775.71
⅜	485.53	549.43	597.17	656.90	712.57	782.77
½	490.12	554.48	602.66	662.91	719.04	789.82
⅝	494.71	559.52	608.15	668.92	725.51	796.88
¾	499.30	564.56	613.65	674.92	731.98	803.93
⅞	503.89	569.61	619.13	680.93	738.44	810.99
12	508.48	574.65	624.63	686.94	744.91	818.04
⅛	513.07	579.69	630.12	692.95	751.38	825.10
¼	517.66	584.73	635.62	698.95	757.85	832.15
⅜	522.25	589.78	641.11	704.97	764.31	839.21
½	526.84	594.82	646.60	710.97	770.78	846.26
⅝	531.43	599.86	652.09	716.98	777.25	853.32
¾	536.02	604.91	657.59	722.98	783.72	860.37
⅞	540.61	609.95	663.08	728.99	790.18	867.43
13	545.20	614.99	668.57	735.00	796.65	874.48
⅛	549.79	620.04	674.06	741.01	803.12	881.54
¼	554.38	625.08	679.56	747.01	809.59	888.59
⅜	558.97	630.13	685.05	753.02	816.05	895.65
½	563.56	635.16	690.54	759.03	822.52	902.70
⅝	568.15	640.21	696.03	765.04	828.99	909.76
¾	572.74	645.25	701.53	771.04	835.46	916.81
⅞	577.33	650.29	707.02	777.05	841.92	923.87
14	581.92	655.34	712.51	783.06	848.39	930.92
⅛	586.51	660.38	718.00	789.07	854.86	937.98
¼	591.10	665.42	723.50	795.07	861.33	945.03
⅜	595.69	670.46	728.99	801.08	867.79	952.09
½	600.28	675.51	734.48	807.09	874.26	959.14
⅝	604.87	680.55	739.98	813.09	880.73	966.20
¾	609.46	685.59	745.47	819.10	887.20	973.25
⅞	614.05	690.64	750.96	825.11	893.66	980.31
15	618.64	695.68	756.45	831.12	900.13	987.36
Weight of 100 Heads						
Button	67.84	90.52	97.35	110.23	124.03	140.76
Cone	87.90	99.50	109.10	130.55	138.40	152.91
Steeple						
Countersunk						
Weight of 100 Shanks 1-in. long	36.72	40.34	43.94	48.06	51.74	56.44

In order to estimate the required amount of rivet shank to form a head, the following table should be consulted.

LENGTH OF RIVETS REQUIRED FOR VARIOUS GRIPS INCLUDING AMOUNT NECESSARY TO FORM ONE HEAD.



Grip of Rivet in Inches.	Diameter of Rivet in Inches.							
	1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	1"	1 1/8"
1/2	1	1 1/4	1 1/2	1 3/4	1 7/8	2	2 1/8	2 1/4
5/8	1 1/8	1 3/8	1 5/8	1 7/8	2	2 1/8	2 1/4	2 3/8
3/4	1 1/4	1 1/2	1 3/4	2	2 1/8	2 1/4	2 3/8	2 1/2
7/8	1 3/8	1 5/8	1 7/8	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8
1	1 1/2	1 3/4	2	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4
1 1/8	1 5/8	1 7/8	2 1/8	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8
1 1/4	1 3/4	2	2 1/4	2 1/2	2 5/8	2 3/4	2 7/8	3
1 3/8	1 7/8	2 1/8	2 3/8	2 5/8	2 7/8	3	3	3 1/8
1 1/2	2	2 1/4	2 1/2	2 3/4	3	3 1/8	3 1/8	3 1/4
1 5/8	2 1/8	2 3/8	2 5/8	2 7/8	3 1/8	3 1/4	3 1/4	3 1/2
1 3/4	2 1/4	2 1/2	2 3/4	3	3 1/4	3 3/8	3 1/2	3 5/8
1 7/8	2 3/8	2 5/8	2 7/8	3 1/4	3 3/8	3 1/2	3 5/8	3 3/4
2	2 1/2	2 3/4	3 1/8	3 3/8	3 1/2	3 5/8	3 3/4	3 7/8
2 1/8	2 5/8	2 7/8	3 1/4	3 1/2	3 5/8	3 3/4	3 7/8	4
2 1/4	2 3/4	3	3 3/8	3 5/8	3 3/4	3 7/8	4	4 1/8
2 3/8	2 7/8	3 1/8	3 1/2	3 3/4	3 7/8	4	4 1/8	4 1/4
2 1/2	3	3 1/4	3 5/8	3 7/8	4	4 1/8	4 1/4	4 3/8
2 5/8	3 1/8	3 1/2	3 3/4	4	4 1/8	4 1/4	4 3/8	4 1/2
2 3/4	3 1/4	3 5/8	3 7/8	4 1/8	4 1/4	4 3/8	4 1/2	4 5/8
2 7/8	3 3/8	3 3/4	4	4 1/4	4 3/8	4 1/2	4 5/8	4 3/4
3	3 1/2	3 7/8	4 1/8	4 3/8	4 1/2	4 5/8	4 3/4	4 7/8
3 1/8	3 5/8	4	4 1/4	4 1/2	4 3/4	4 3/4	5	5
3 1/4	3 3/4	4 1/8	4 3/8	4 3/4	4 7/8	5	5 1/8	5 1/4
3 3/8	3 7/8	4 1/4	4 1/2	4 7/8	5	5 1/8	5 1/4	5 3/8
3 1/2	4	4 3/8	4 5/8	5	5 1/8	5 1/4	5 3/8	5 1/2
3 5/8	4 1/8	4 1/2	4 3/4	5 1/8	5 1/4	5 3/8	5 1/2	5 5/8
3 3/4	4 1/4	4 5/8	4 7/8	5 1/4	5 3/8	5 1/2	5 5/8	5 3/4
3 7/8	4 3/8	4 3/4	5	5 3/8	5 1/2	5 5/8	5 3/4	5 7/8
4	4 1/2	4 7/8	5 1/8	5 1/2	5 5/8	5 3/4	5 7/8	6
4 1/8	4 5/8	5	5 1/4	5 5/8	5 3/4	5 7/8	6	6 1/8
4 1/4	4 3/4	5 1/8	5 1/2	5 3/4	5 7/8	6	6 1/8	6 1/4
4 3/8	4 7/8	5 1/4	5 5/8	5 7/8	6	6 1/8	6 1/4	6 3/8
4 1/2	5	5 3/8	5 3/4	6	6 1/8	6 1/4	6 3/8	6 1/2
4 5/8	5 1/8	5 1/2	5 7/8	6 1/8	6 1/4	6 3/8	6 1/2	6 5/8
4 3/4	5 1/4	5 5/8	6	6 1/4	6 1/2	6 5/8	6 3/4	6 3/4
4 7/8	5 3/8	5 3/4	6 1/8	6 1/2	6 5/8	6 3/4	6 7/8	6 7/8
5	5 1/2	5 7/8	6 1/4	6 5/8	6 3/4	6 7/8	7	7
5 1/8	5 5/8	6	6 3/8	6 3/4	6 7/8	7	7 1/8	7 1/8
5 1/4	5 3/4	6 1/8	6 1/2	6 7/8	7	7 1/8	7 1/4	7 1/4
5 3/8	5 7/8	6 1/4	6 5/8	7	7 1/8	7 1/4	7 3/8	7 3/8
5 1/2	6	6 3/8	6 3/4	7 1/8	7 1/4	7 3/8	7 1/2	7 1/2
5 5/8	6 1/8	6 1/2	6 7/8	7 1/4	7 3/8	7 1/2	7 5/8	7 5/8
5 3/4	6 1/4	6 3/4	7	7 3/8	7 5/8	7 5/8	7 3/4	7 3/4
5 7/8	6 3/8	6 7/8	7 1/8	7 1/2	7 3/4	7 3/4	7 7/8	7 7/8
6	6 1/2	7	7 1/4	7 5/8	7 7/8	7 7/8	8	8 1/8

Amount in Inches to be subtracted from above lengths for Countersunk Heads.

	1/8	1/4	1/2	1/2	5/8	3/4	7/8	7/8

Following is a table of Areas deducted from Plates or Shapes due to the Punching, hence a ready method of obtaining Net Areas.

TABLES OF AREAS IN SQUARE INCHES, TO BE DEDUCTED FROM RIVETED PLATES OR SHAPES TO OBTAIN NET AREAS.

SIZE OF HOLE. Inches.

Thickness Plates in Inches.	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/16	1 1/8	1 3/16	1 1/4	1 5/16	1 3/8	1 7/16	1 1/2	1 9/16	1 5/8	1 11/16	1 3/4	1 13/16	1 7/8	1 15/16	2	Thickness Plates. in inches.
1/4	.06	.08	.09	.11	.13	.14	.16	.17	.19	.20	.22	.23	.25	.27	.28	.30	.31	.33	.34	.36	.38	.39	.41	.42	.44	.45	.47	.48	.50	1/4
5/16	.08	.10	.12	.14	.16	.18	.20	.21	.23	.25	.27	.29	.31	.33	.35	.37	.39	.41	.43	.45	.47	.49	.51	.53	.55	.57	.59	.61	.63	5/16
3/8	.09	.12	.14	.16	.19	.21	.23	.26	.28	.30	.33	.35	.38	.40	.42	.45	.47	.49	.52	.54	.56	.59	.61	.63	.66	.68	.70	.73	.75	3/8
7/16	.11	.14	.16	.19	.22	.25	.27	.30	.33	.36	.38	.41	.44	.46	.49	.52	.55	.57	.60	.63	.66	.68	.71	.74	.77	.79	.82	.85	.88	7/16
1/2	.13	.16	.19	.22	.25	.28	.31	.34	.38	.41	.44	.47	.50	.53	.56	.59	.63	.66	.69	.72	.75	.78	.81	.84	.88	.91	.94	.97	1.00	1/2
9/16	.14	.18	.21	.25	.28	.32	.35	.39	.42	.46	.49	.53	.56	.60	.63	.67	.70	.74	.77	.81	.84	.88	.91	.95	.98	1.02	1.05	1.09	1.13	9/16
5/8	.16	.20	.23	.27	.31	.35	.39	.43	.47	.51	.55	.59	.63	.66	.70	.74	.78	.82	.86	.90	.94	.98	1.02	1.05	1.09	1.13	1.17	1.21	1.25	5/8
11/16	.17	.21	.26	.30	.34	.39	.43	.47	.52	.56	.60	.64	.69	.73	.77	.82	.86	.90	.95	.99	1.03	1.07	1.12	1.16	1.20	1.25	1.29	1.33	1.38	11/16
3/4	.19	.23	.28	.33	.38	.42	.47	.52	.56	.61	.66	.70	.75	.80	.84	.89	.94	.98	1.03	1.08	1.13	1.17	1.22	1.27	1.31	1.36	1.41	1.45	1.50	3/4
13/16	.20	.25	.30	.36	.41	.46	.51	.56	.61	.66	.71	.76	.81	.86	.91	.96	1.02	1.07	1.12	1.17	1.22	1.27	1.32	1.37	1.42	1.47	1.52	1.57	1.63	13/16
7/8	.22	.27	.33	.38	.44	.49	.55	.60	.66	.71	.77	.82	.88	.93	.98	1.01	1.09	1.15	1.20	1.26	1.31	1.37	1.42	1.48	1.53	1.59	1.64	1.70	1.75	7/8
15/16	.23	.29	.35	.41	.47	.53	.59	.64	.70	.76	.82	.88	.94	1.00	1.05	1.11	1.17	1.23	1.29	1.35	1.41	1.46	1.52	1.58	1.64	1.70	1.76	1.82	1.88	15/16
1	.25	.31	.38	.44	.50	.56	.63	.69	.75	.81	.88	.94	1.00	1.06	1.13	1.19	1.25	1.31	1.38	1.44	1.50	1.56	1.63	1.69	1.75	1.81	1.88	1.94	2.00	1
1 1/16	.27	.33	.40	.46	.53	.60	.66	.73	.80	.86	.93	1.00	1.06	1.13	1.20	1.26	1.33	1.39	1.46	1.53	1.59	1.66	1.73	1.79	1.86	1.93	1.99	2.06	2.13	1 1/16
1 1/8	.28	.35	.42	.49	.56	.63	.70	.77	.84	.91	.98	1.05	1.13	1.20	1.27	1.34	1.41	1.48	1.55	1.62	1.69	1.76	1.83	1.90	1.97	2.04	2.11	2.18	2.25	1 1/8
1 3/16	.30	.37	.45	.52	.59	.67	.74	.82	.89	.96	1.04	1.11	1.19	1.26	1.34	1.41	1.48	1.56	1.63	1.71	1.78	1.86	1.93	2.00	2.08	2.15	2.23	2.30	2.38	1 3/16
1 1/4	.31	.39	.47	.55	.63	.70	.78	.86	.94	1.02	1.09	1.17	1.25	1.33	1.41	1.48	1.56	1.64	1.72	1.80	1.88	1.95	2.03	2.11	2.19	2.27	2.34	2.42	2.50	1 1/4
1 5/16	.33	.41	.49	.57	.66	.74	.82	.90	.98	1.07	1.15	1.23	1.31	1.39	1.48	1.56	1.64	1.72	1.80	1.89	1.97	2.05	2.13	2.21	2.30	2.38	2.46	2.54	2.63	1 5/16
1 3/8	.34	.43	.52	.60	.69	.77	.86	.95	1.03	1.12	1.20	1.29	1.38	1.46	1.55	1.63	1.72	1.80	1.89	1.98	2.06	2.15	2.23	2.32	2.41	2.49	2.58	2.66	2.75	1 3/8
1 7/16	.36	.45	.54	.63	.72	.81	.90	.99	1.08	1.17	1.26	1.35	1.44	1.53	1.62	1.71	1.80	1.89	1.98	2.07	2.16	2.25	2.34	2.43	2.52	2.61	2.70	2.79	2.88	1 7/16
1 1/2	.38	.47	.56	.66	.75	.84	.94	1.03	1.13	1.22	1.31	1.41	1.50	1.59	1.69	1.78	1.88	1.97	2.06	2.16	2.25	2.34	2.44	2.53	2.63	2.72	2.81	2.91	3.00	1 1/2
1 9/16	.39	.49	.59	.68	.78	.88	.98	1.07	1.17	1.27	1.37	1.46	1.56	1.66	1.76	1.86	1.95	2.05	2.15	2.25	2.34	2.44	2.54	2.64	2.73	2.83	2.93	3.03	3.13	1 9/16
1 5/8	.41	.51	.61	.71	.81	.91	1.02	1.12	1.22	1.32	1.42	1.52	1.63	1.73	1.83	1.93	2.03	2.13	2.23	2.34	2.44	2.54	2.64	2.74	2.84	2.95	3.05	3.15	3.25	1 5/8
1 11/16	.42	.53	.63	.74	.84	.95	1.05	1.16	1.27	1.37	1.47	1.58	1.69	1.79	1.90	2.00	2.11	2.21	2.32	2.43	2.53	2.64	2.74	2.85	2.95	3.06	3.16	3.27	3.38	1 11/16
1 3/4	.44	.55	.66	.77	.88	.98	1.09	1.20	1.31	1.42	1.53	1.64	1.75	1.86	1.97	2.08	2.19	2.30	2.41	2.52	2.63	2.73	2.84	2.95	3.06	3.17	3.28	3.39	3.50	1 3/4
1 13/16	.45	.57	.68	.79	.91	1.02	1.13	1.25	1.36	1.47	1.59	1.70	1.81	1.93	2.04	2.15	2.27	2.38	2.49	2.61	2.72	2.83	2.95	3.06	3.17	3.29	3.40	3.51	3.63	1 13/16
1 7/8	.47	.59	.70	.82	.94	1.05	1.17	1.29	1.41	1.52	1.64	1.76	1.88	1.99	2.11	2.23	2.34	2.46	2.58	2.70	2.81	2.93	3.05	3.16	3.28	3.40	3.52	3.63	3.75	1 7/8
1 15/16	.48	.61	.73	.85	.97	1.09	1.21	1.33	1.45	1.57	1.70	1.82	1.94	2.06	2.18	2.30	2.42	2.54	2.66	2.79	2.91	3.03	3.15	3.27	3.39	3.51	3.63	3.75	3.88	1 15/16
2	.50	.63	.75	.88	1.00	1.13	1.25	1.38	1.50	1.63	1.75	1.88	2.00	2.13	2.25	2.38	2.50	2.63	2.75	2.88	3.00	3.13	3.25	3.38	3.50	3.63	3.75	3.88	4.00	2

In the design of Riveted joints for structural purposes the total stress transmitted is assumed to be taken up by the rivets, no allowance being made for friction of the plates riveted together. The manner of failure is assumed as the shearing of the rivets, or the crushing of the plate.

The following observations are consistant with good design, and the recommendations of the American Bridge Company will first be given.

(1.) The riveted parts of structures shall be designed so that the stress shall not exceed the following amounts in pounds per square inch.
Shear on Shop Rivets .... 12000 pounds per sq. in.
Shear on Field Rivets .... 10000 pounds per sq. in.
Bearing pressure on Shop Rivets .... 24000 pounds per sq. in.
Bearing pressure on Field Rivets .... 20000 pounds per sq. in.

(2). No connections, excepting lattice bars, shall have less than 2 rivets.

(3). Trusses shall preferably be riveted structures.

(4). The minimum distance between centers of rivet holes shall be three diameters of the rivet.

(5). The distance from center to center of rivet holes shall preferably be not less than:

$3''$ for $\frac{7}{8}''$ rivets.
$2\frac{1}{2}''$ for $\frac{3}{4}''$ rivets.
$2''$ for $\frac{5}{8}''$ rivets.
$1\frac{3}{4}''$ for $\frac{1}{2}''$ rivets.

(6). The maximum pitch in the line of stress for members composed of plates and shapes will be:

$6''$ for $\frac{7}{8}''$ rivets.
$6''$ for $\frac{3}{4}''$ rivets.
$4\frac{1}{2}''$ for $\frac{5}{8}''$ rivets.
$4''$ for $\frac{1}{2}''$ rivets.

(7). The maximum pitch for angles in built up sections with two gage lines with rivets staggered shall be twice that given in (6).

(8). Where two or more plates are in contact, rivets not more than 12 inches apart in either direction shall be used to hold the plates together.

(9). The minimum distance from the center of any rivet hole to a sheared edge shall be:

$1\frac{1}{2}''$ for $\frac{7}{8}''$ rivets.
$1\frac{1}{4}''$ for $\frac{3}{4}''$ rivets.
$1\frac{1}{8}''$ for $\frac{5}{8}''$ rivets.
$1''$ for $\frac{1}{2}''$ rivets.

(10). The minimum distance from the center of any rivet hole to a Rolled edge shall be:

$1\frac{1}{4}''$ for $\frac{7}{8}''$ rivets.
$1\frac{1}{8}''$ for $\frac{3}{4}''$ rivets.
$1''$ for $\frac{5}{8}''$ rivets.
$\frac{7}{8}''$ for $\frac{1}{2}''$ rivets.

(11). The maximum distance from the center of any rivet hole to the edge of a plate shall be 8 times the thickness of the plate.

(12). The Pitch of the rivets at the ends of built up compression members shall not exceed 4 diameters of the rivet for a length equal to $1\frac{1}{2}$ times the maximum width of the member.

(13). In the construction of lattice work, the following minimum requirements must be met:

Size of Channel	Or Built Section of	Minimum Width	Size Rivets
15″	3½″ & 4″ Angles	2½″	⅞″
12, 10 or 9″	3″ Angles	2¼″	¾″
8 or 7″	2½″ Angles	2″	⅝″
6 or 5″	2″ Angles	1¾″	½″

(14). The Pitch of rivets shall not exceed 6 inches, or 16 times the thickness of the thinnest outside plate.

(15). In the flanges of Beams and Girders where plates more than 12 inches wide are used, an extra line of rivets having a pitch not greater than 9 inches should be driven along each edge to draw the plates together.

(16). At the ends of Compression members the pitch should not exceed 4 diameters of the rivet for a length equal to twice the width or diameter of the member.

(17). In the flanges of girders or chords carrying floors the pitch shall not exceed 4 inches.

(18). For plates in compression the pitch in the line of stress should not exceed 16 times the thickness of the plate, and the pitch at right angles to the line of stress should not exceed 32 times the thickness.

(19). For cover plates or top chords and end posts, the pitch should not exceed 40 times their thickness.

(20). In chain riveting the distance between the center lines of adjacent rows should preferably be not less than 3 diameters of the rivet, and never less than $2\frac{1}{2}$ diameters.

(21). In Zigzag or Staggered Riveting, the distance between the center lines of adjacent rows shall preferably be not less than $2\frac{1}{2}$ times the diameter of the rivet, and never less than 2 times the diameter.

(22). The grip of a rivet (length between heads as driven), should never exceed 4 times the diameter of the rivet.

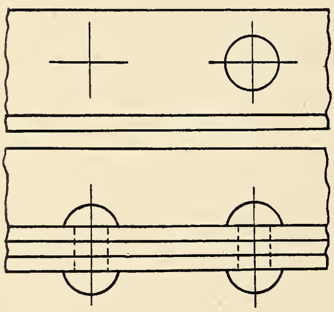
(23). Countersunk rivets shall not be used in plates of less thickness than $\frac{1}{2}$ the diameter of the rivet.

A large part of the work in designing of Steel structures consists in getting instructions inserted into drawings. In order to designate the type of rivet and the kind of head to be formed, the following conventional scheme is used. Cuts 52 to 57 illustrate them.

CONVENTIONAL SIGNS USED IN RIVETING DESIGN

Shop Rivets—Two Full Heads

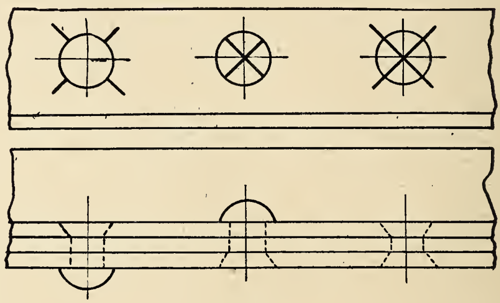
SHOP RIVETS
TWO FULL HEADS.



Cut 52.

SHOP RIVETS—COUNTERSUNK AND
CHIPPED.

Near Side. Far Side. Both Sides.

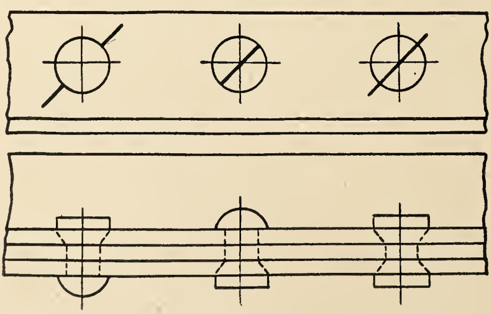


Cut 53.

SHOP RIVETS—COUNTERSUNK BUT NOT CHIPPED.

Maximum height, $\frac{1}{8}$ inch.

Near Side Far Side Both Sides

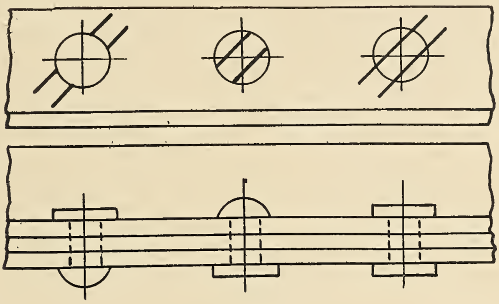


Cut 54.

SHOP RIVETS—FLATTENED TO 1/4 INCH HIGH.

$\frac{1}{2}''$ and $\frac{5}{8}''$ Rivets.

Near Side Far Side Both Sides

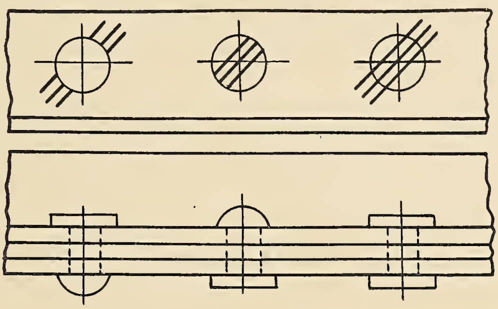


Cut 55.

SHOP RIVETS—FLATTENED TO 3/8 INCHES HIGH.

$\frac{3}{4}''$, $\frac{7}{8}''$ and $1''$ Rivets.

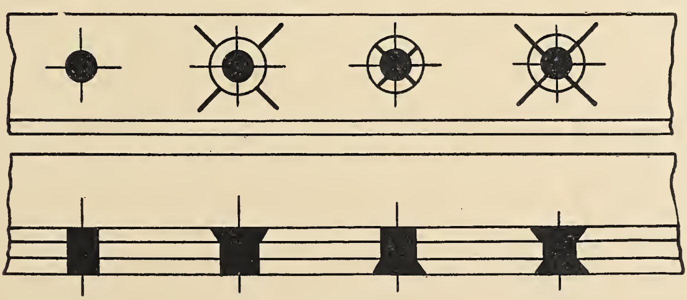
Near Side Far Side Both Sides



Cut 56.

FIELD RIVETS—COUNTERSUNK AND CHIPPED.

Two Full Heads Near Side Far Side Both Sides



Cut 57.

As a logical table at this point we give a tabulation of Shearing and Bearing Values for Rivets of different diameter. Unless special values are called for in any particular city building ordnance, it is customary to use the following:

Shearing value of 12000 pounds per square inch for Shop Rivets.
Shearing value of 10000 pounds per square inch for Field Rivets.
In the following table, Cut 58, Bearing Values are as follows:
Above or to Right of Upper Zigzag line greater than double shear.
Below or to Left of Lower Zigzag line are less than single shear.
Between Upper and Lower Zigzag lines they are less than double shear but greater than single shear.

Diameter of Rivet, Inches	Area, Square Inches	Single Shear at 7,500 Pounds	Bearing Value in Pounds for Different Thickness of Plate in Inches at 15,000 Pounds per Square Inch												
			¼	5/16	⅜	7/16	½	9/16	⅝	11/16	¾	13/16	⅞	15/16	1
⅜	.1104	830	1410	1760	2110	......	......	......	......	......	......	......	......	......	......
½	.1963	1470	1880	2340	2810	3280	3750	......	......	......	......	......	......	......	......
⅝	.3068	2300	2340	2930	3520	4100	4690	5280	5860	......	......	......	......	......	......
¾	.4418	3310	2810	3520	4220	4920	5630	6330	7030	7720	8440	......	......	......	......
⅞	.6013	4510	3280	4100	4920	5740	6560	7380	8200	9030	9850	10670	11480	12300	......
1	.7854	5890	3750	4690	5620	6560	7500	8440	9380	10310	11250	12190	13130	14060	15000

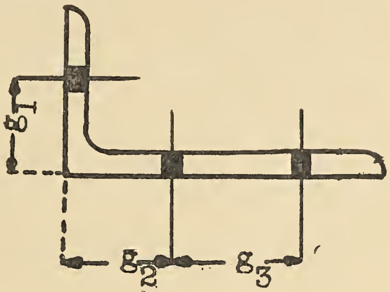
Diameter of Rivet, Inches	Area, Square Inches	Single Shear at 9,000 Pounds	Bearing Value in Pounds for Different Thickness of Plate in Inches at 18,000 Pounds per Square Inch												
			¼	5/16	⅜	7/16	½	9/16	⅝	11/16	¾	13/16	⅞	15/16	1
⅜	.1104	990	1680	2110	2530	......	......	......	......	......	......	......	......	......	......
½	.1963	1770	2250	2820	3370	3940	4500	......	......	......	......	......	......	......	......
⅝	.3068	2760	2790	3480	4180	4870	5580	6330	7030	......	......	......	......	......	......
¾	.4418	3970	3370	4210	5050	5910	6750	7590	8440	9280	10130	......	......	......	......
⅞	.6013	5410	3940	4920	5910	6880	7870	8860	9840	10830	11810	12800	13780	14770	......
1	.7854	7060	4500	5620	6750	7870	9000	10120	11250	12370	13500	14630	15750	16880	18000

Diameter of Rivet, Inches	Area, Square Inches	Single Shear at 10,000 Pounds	Bearing Value in Pounds for Different Thickness of Plate in Inches at 20,000 Pounds per Square Inch												
			¼	5/16	⅜	7/16	½	9/16	⅝	11/16	¾	13/16	⅞	15/16	1
⅜	.1104	1100	1880	2340	2810	......	......	......	......	......	......	......	......	......	......
½	.1963	1960	2500	3130	3750	4380	5000	......	......	......	......	......	......	......	......
⅝	.3068	3070	3130	3910	4690	5470	6250	7030	7810	......	......	......	......	......	......
¾	,4418	4420	3750	4690	5630	6560	7500	8440	9380	10310	11250	......	......	......	......
⅞	.6013	6010	4380	5470	6570	7660	8750	9840	10940	12030	13130	14220	15310	16410	......
1	.7854	7850	5000	6250	7500	8750	10000	11250	12500	13750	15000	16250	17500	18750	20000

Diameter of Rivet, Inches	Area, Square Inches	Single Shear at 12,000 Pounds	Bearing Value in Pounds for Different Thickness of Plate in Inches at 24,000 Pounds per Square Inch												
			¼	5/16	⅜	7/16	½	9/16	⅝	11/16	¾	13/16	⅞	15/16	1
⅜	.1104	1320	2250	2810	3380	......	......	......	......	......	......	......	......	......	......
¼	.1963	2360	3000	3750	4500	5250	6000	......	......	......	......	......	......	......	......
⅝	.3068	3680	3750	4690	5630	6560	7500	8440	9380	......	......	......	......	......	......
¾	.4418	5300	4500	5630	6750	7880	9000	10130	11250	12380	13500	......	......	......	......
⅞	.6013	7220	5250	6560	7880	9190	10500	11810	13130	14440	15750	17060	18380	......	......
1	.7854	9430	6000	7500	9000	10500	12000	13500	15000	16500	18000	19500	21000	22500	24000

Cut 58.

Mention has been made of certain standards to be observed in general design, and supplementing those axioms we herewith include cuts and tables covering standard practice.



Cut 59.

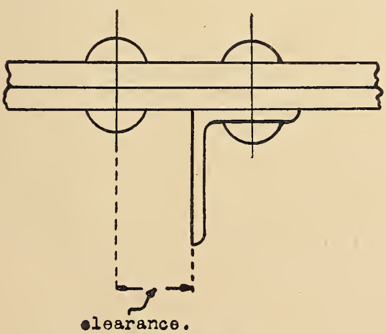
Leg.	8	7	6	5	4	3½	3	2½	2
g_1	4½	4	3½	3	2½	2	1¾	1⅜	1⅛
g_2	3	2½	2½	2	...	...	...	...	...
g_3	3	3	2¼	1¾	...	...	...	...	...
Max. Rivet	1⅛	1	⅞	⅞	⅞	⅞	⅞	¾	⅝

Leg.	1¾	1½	1⅜	1¼	1	¾
g_1..........	1	⅞	⅞	¾	⅝	½
Max. Rivet..	½	⅜	⅜	⅜	¼	¼

For column details, 6 inch leg, and ½ inch thick or less, against a column shaft, "g_2" = 1¾″, "g_3" = 3″.

For diagonal angles, etc., gage in middle where riveted leg equals or exceeds 3″ for ¾″ rivets, 3½″ for ⅞″ rivets.

Use special gages to adapt work to multiple punch, or to secure desirable details.



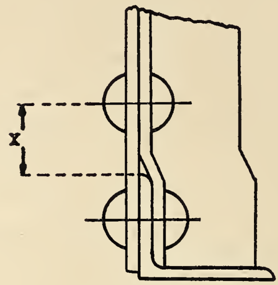
Cut 60.

CLEARANCE FOR WEB RIVETING

For Rivets	Standard Clearance	Minimum Clearance
⅝″	1⅛″	⅞″
¾″	1¼″	1″
⅞″	1⅜″	1⅛″
1″	1½″	1¼″
1⅛″	1⅝″	1⅜″

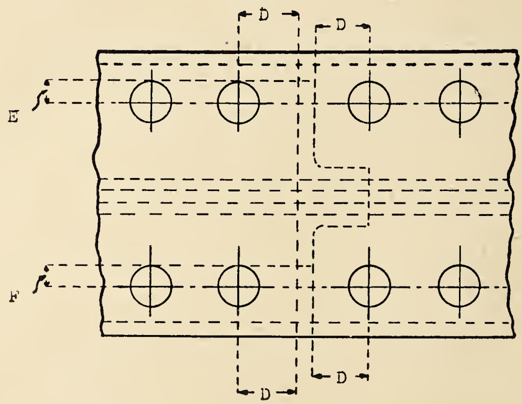
RIVETS IN CRIMPED ANGLES

The distance "X" should be 1½″ plus thickness of chord angles, and never less than 2″.



Cut 61.

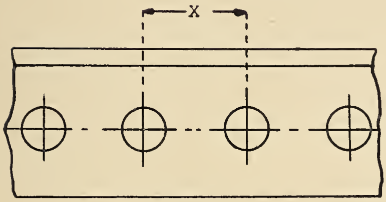
CLEARANCE FOR COVER PLATE RIVETING



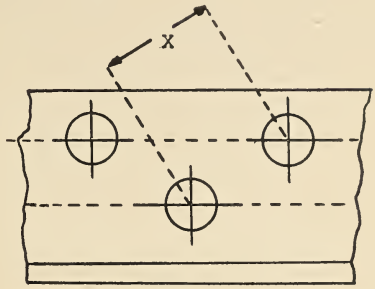
Cut 62.

E =	½″	1″	1½″	2″	2½″	3″
D =	2½″	2⅝″	2¾″	2¾″	2⅞″	2⅞″
E =	3½″	4″	4½″	5″	5½″	6″
D =	3″	3⅛″	3⅛″	3¼″	3¼″	3⅜″
F =	0.	½″	1″	1½″	2″	2½″
D =	2½″	2¼″	2⅛″	2″	1½″	0.

MINIMUM RIVET SPACING



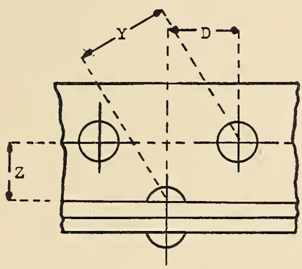
Cut 67.



Cut 68.

Diameter of Rivet.	Min. Spacing "X."	Diameter of Rivet.	Min. Spacing "X."
1/4"	1"	3/4"	2 1/4"
3/8"	1 1/4"	7/8"	2 5/8"
1/2"	1 3/4"	1"	3"
5/8"	2"	1 1/8"	3 3/8"

MINIMUM STAGGER FOR RIVETS



Cut 65.

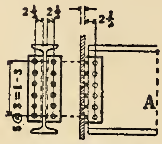
Rivets Diameter.	Value of Y.	Rivets Diameter.	Value of Y.
5/8"	1"	1"	1 3/8"
3/4"	1 1/8"	1 1/8"	1 1/2"
7/8"	1 1/4"		

Minimum Stagger "D," in inches for values of "Z," in inches.

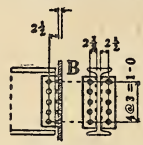
Z. Inches	for 5/8" rivet	3/4" rivet	7/8" rivet	1" rivet	1 1/8" rivet
1 1/8"	15/16"	1 1/4"	1 1/2"	1 13/16"	2 1/16"
1 3/16"	7/8"	1 3/16"	1 7/16"	1 3/4"	2"
1 1/4"	13/16"	1 1/8"	1 3/8"	1 11/16"	1 15/16"
1 5/16"	11/16"	1 1/16"	1 5/16"	1 5/8"	1 15/16"
1 3/8"	1/2"	15/16"	1 1/4"	1 9/16"	1 7/8"
1 7/16"	5/16"	7/8"	1 3/16"	1 1/2"	1 13/16"
1 1/2"	0	3/4"	1 1/8"	1 7/16"	1 3/4"
1 9/16"		9/16"	1"	1 3/8"	1 11/16"
1 5/8"		3/8"	15/16"	1 5/16"	1 5/8"
1 11/16"		0	13/16"	1 3/16"	1 9/16"
1 3/4"			5/8"	1 1/8"	1 1/2"
1 13/16"			7/16"	1 1/8"	1 3/8"
1 7/8"			0	1 7/8"	1 5/16"
1 15/16"				3/4"	1 1/4"
2 1/16"				0	1"
2 3/16"					1 11/16"
2 5/16"					0

When Beams and Channels are considered, Rivet Spacing and Rivet Diameter for different weights and sections have been standardized. There is a slight difference in these standards depending on the source of the Rolled Sections, and for a complete understanding two sets of these standards are published herein, they being representative of the largest concerns standards.

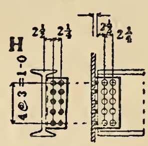
STANDARD CONNECTIONS FOR STANDARD BEAMS AND CHANNELS



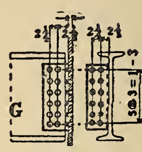
Double Angle Conn. for 24-in. Beams



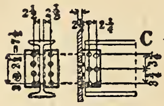
Double Angle Conn. for 18-in. and 20-in. Beams



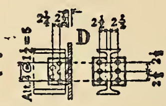
Single Angle Conn. for 18-in. and 20-in. Beams



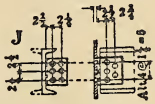
Single Angle Conn. for 24-in. Beams



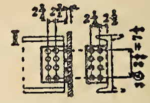
Double Angle Conn. for 15-in. Beams, 15-in. and 13-in. Channels



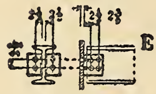
Double Angle Conn. for 12-in. Beams and 12 in. Channels



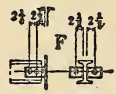
Single Angle Conn. for 12-in. Beams and 12-in. Channels



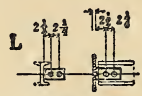
Single Angle Conn. for 15-in. Beams, 15-in. and 13-in. Channels



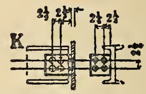
Double Angle Conn. for 7, 8, 9 and 10-in. Beams and Channels



Double Angle Conn. for 3, 4, 5 and 10-in. Beams and Channels



Single Angle Conn. for 3, 4, 5 and 6-in. Beams and Channels



Single Angle Conn. for 7, 8, 9 and 10-in. Beams and Channels

Ends of beams having Standard Connections should be cut at least ¼ inch short of distance to face of each connection and preferably ½ inch short, to allow for over-run in cutting.

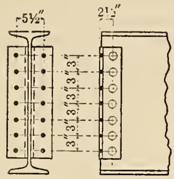
For dimensions not given see tables of Weights and Dimensions of Standard Beams and Channels.

Double and Single Connections	Size		Minimum Strength of one Connection in Pounds	Wght. Angles only	Wght. Angles and Shop Rivets	Wght. including Field Rivets	Diam. of Rivets	Diam. of Holes
A	Two 4x4x $\frac{7}{16}$ Angles 1 ft. 6 in. long......	Bearing Value {Shop Rivets = 24000 lbs. sq. in. / Field Rivets = 20000 lbs. sq. in.} Shear {12000 lbs. / 10000 lbs.}	54000	34 0	37.0	43.0	¾	13/16
B	Two 4x4x $\frac{7}{16}$ Angles 1 ft. 3 in. long......		45000	28.2	30.7	36.0	¾	13/16
C	Two 6x4x $\frac{7}{16}$ Angles. 0 ft. 10 in. long......		40500	23 8	26 9	31.0	¾	13/16
D	Two 6x4x $\frac{7}{16}$ Angles 0 ft. 7½ in. long.....		33750	17 9	20.3	23.0	¾	13/16
E	Two 6x4x $\frac{7}{16}$ Angles 0 ft. 5 in. long......		18000	11 9	13.8	16.0	¾	13/16
F	Two 6x4x $\frac{7}{16}$ Angles 0 ft. 3 in. long....... (0 ft. 2½ in. long for 5 Is, 0 ft. 2 in. long for 3 and 4 in.).........		6750	7 1	8.0	9.0	¾	13/16
G	One 6x6x $\frac{7}{16}$ Angle 1 ft. 6 in. long.......		53040	25.8	31.1	36.0	¾	13/16
H	One 6x6x $\frac{7}{16}$ Angle 1 ft. 3 in. long.......		44200	21.5	25.9	30.0	¾	13/16
I	One 6x6x $\frac{7}{16}$ Angle 0 ft. 10 in. long......		35360	14.3	18.0	22.0	¾	13/16
J	One 6x6x $\frac{7}{16}$ Angle 0 ft. 7½ in. long.....		26520	10.7	12.8	15.0	¾	13/16
K	One 6x6x $\frac{7}{16}$ Angle 0 ft. 5 in. long.......		15000	7.1	8.7	10.0	¾	13/16
L	One 6x6x $\frac{7}{16}$ Angle 0 ft. 3 in. long...... (0 ft. 2½ in. long for 5 Is, 0 ft. 2 in. long for 3 and 4 in.) ...		5625	4.3	5.1	6.0	¾	13/16

Beams or Channels should not be loaded with a greater uniformly distributed load (including the weight of the beam) than twice the "minimum strength of one connection," when Standard Connections are used, except as shown by the tables of Safe Loads of Beams and Channels.

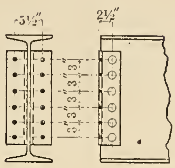
Cut 69.

27″



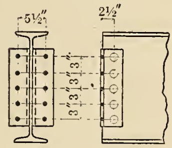
2 Ls 4″x 4″x ½″x 1′-8½″
Weight 46 lbs.

24″



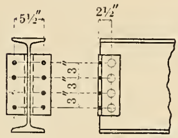
2 Ls 4″x 4″x ½″x 1′-5½″
Weight 39 lbs.

21″



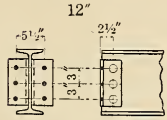
2 Ls 4″x 4″x ½″x 1′-2½″
Weight 33 lbs.

20,″ 18,″ 15″



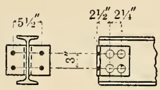
2 Ls 4″x 4″x 7/16″x 0′-11½″
Weight 23 lbs.

12″



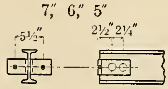
2 Ls 4″x 4″x 7/16″x 0′-8½″
Weight 17 lbs.

10,″ 9,″ 8″



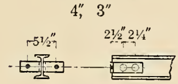
2 Ls 6″x 4″x ⅜″x 0′-5½″
Weight 13 lbs.

7,″ 6,″ 5″



2 Ls 6″x 4″x ⅜″x 0′-3″
Weight 7 lbs.

4,″ 3″



2 Ls 6″x 4″x ⅜″x 0-2″
Weight 5 lbs.

Limiting Values of Beam Connections

I Beams		Value of Web Connection	Values of Outstanding Legs of Connection Angles					
			Field Rivets			Field Bolts		
Depth, Inches	Weight Pounds per Foot.	Shop Rivets in Enclosed Bearing, Pounds	¾″ Rivets or Turned Bolts, Single Shear, Pounds	Minimum Allowable Span in Feet, Uniform Load	t, In.	¾″ Rough Bolts, Single Shear, Pounds	Minimum Allowable Span in Feet, Uniform Load	t, In.
27	83	66800	61900	18.4	⅝	49500	23.1	⅝
24	80	67500	53000	17.5	⅝	42400	21.9	⅝
	69½	52700	53000	16.3	⅝	42400	20.2	⅝
21	57½	40200	44200	15.5	9/16	35300	17.6	⅝
20	65	45000	35300	17.6	⅝	28300	22.1	⅝
18	55	41400	35300	13.3	⅝	28300	16.7	⅝
	46	29000	35300	15.0	½	28300	15.4	⅝
15	42	36900	35300	8.9	⅝	28300	11.1	⅝
	36	26000	35300	11.1	7/16	28300	11.1	9/16
12	31½	23600	26500	8.1	9/16	21200	9.0	⅝
	27½	17200	26500	10 3	7/16	21200	10.3	½
10	25	27900	17700	7.4	⅝	14100	9.2	⅝
	22	20900	17700	6.9	⅝	14100	8.6	⅝
9	21	26100	17700	5.7	⅝	14100	7.1	⅝
8	18	24300	17700	4.3	⅝	14100	5.4	⅝
	17½	18900	17700	4.4	⅝	14100	5.5	⅝
7	15	11300	8800	6.2	⅝	7100	7.8	⅝
6	12¼	10400	8800	4.4	⅝	7100	5.5	⅝
5	9¾	9500	8800	2.9	⅝	7100	3.6	⅝
4	7½	8600	8800	2.2	9/16	7100	2.7	⅝
3	5½	7700	8800	1.3	½	7100	1.4	⅝

Cut 70.

The connections as given on page 97 were figured using the following data:

Rivets and bolts ¾″ diameter.

Weights given are for ¾-inch shop rivets and angle connections; about 20 per cent should be added for field rivets or bolts.

ALLOWABLE UNIT STRESS IN POUNDS PER SQUARE INCH

Single Shear	Rivets ....Shop 12000 Rivets and Turned Bolts...Field 10000 Rough Bolts ....Field 8000	Bearing	Rivets—enclosed.......Shop 30000 Rivets—one side.......Shop 24000 Rivets and Turned Bolts, Field 20000 Rough Bolts............Field 16000

t=Web thickness, in bearing, to develop max. allowable reactions, when beams frame opposite.

Connections are figured for bearing and shear (no moment considered).

The above values agree with tests made on beams under ordinary conditions of use.

Where web is enclosed between connection angles (enclosed bearing), values are greater because of the increased efficiency due to friction and grip.

Special connections shall be used when any of the limiting conditions given above are exceeded—such as end reaction from loaded beam being greater than value of connection; shorter span with beam fully loaded; or a less thickness of web when maximum allowable reactions are used.

The following points should be observed in the punching of plates and shapes, and the driving of rivets.

In punching rivet holes the diameter of the punch should not be more than 1/16″, nor the die more than ⅛″ larger in diameter than the diameter of the rivet. Punching should be done accurately, although in structural work slight inaccuracy in the mating and matching of holes can be corrected by the reamer. Drifting to enlarge unfair holes should not be allowed.

Rivets should be driven with pressure tools whenever possible, and Pneumatic hammers are preferred in place of hand driving. Rivets should look neat and finished, and with the proper heads, and the heads of equal size. Contact surfaces should be painted prior to riveting, and all parts pinned up and bolted before riveting commences.

Recupping and calking of loose rivets should never be allowed. The loose rivet should be cut out and another driven. Burned rivets should likewise be cut out and replaced. In cutting out rivets care should be taken not to gouge or injure the plates. If necessary, loose rivets should be drilled out. Reamed holes should be circular and cylindrical and perpendicular to the surface of the member.

The Navy Department requires some observances not usually specified in commercial specifications, and which are worth noting.

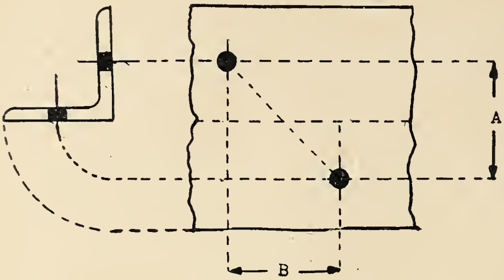
In structural steel work the pitch of the rivets shall not be less than three times the diameter of the rivet, and not greater than six inches or

16 times the thickness of the thinnest outside section. All punching must be accurately done, and drifting to match or enlarge unfair holes will not be allowed. If the holes must be enlarged to admit the rivet they shall be reamed. When general reaming is not required, the diameter of the punch shall not be more than 1/16″ greater than the diameter of the rivet, nor the die nore than $\frac{1}{8}$″ greater than the diameter of the punch. Material more than $\frac{3}{4}$″ thick may be subpunched and reamed, or drilled from the solid. When reaming is required by the contract the punch used shall have a diameter not less than 3/16″ smaller than the nominal diameter of the rivet. Reaming shall be done after the pieces forming one built up member are assembled and firmly bolted together, using drills or reamers having a diameter 1/16″ larger than the nominal diameter of the rivet. Outside burrs on reamed holes shall be removed.

In erecting all field connections shall be riveted, unless the use of bolts is allowed in the contract. The various members forming parts of a completed structure after being assembled shall be accurately aligned before riveting is begun. After erection the heads of field rivets shall be painted, this being done promptly after their acceptance. The rivet heads shall be cleaned from mill scale before painting.

In the construction of large mill buildings, such as are used in our Steel plants, and general engineering activities, approximately two field rivets are required per square foot of covered area, in the erection of such buildings. Thus in a building some 656 feet long, and 200 feet wide, and covering an area of approximately 131,600 square feet, this building weighing complete some 7000 tons, there were driven some 225,000 Field rivets in its assembly. The number of Field rivets that a Riveting gang can drive per day depends upon the location in the structure. A gang of three men on average building erection should drive approximately from 225 to 250 Field rivets in 8 hours.

STAGGER OF RIVETS TO MAINTAIN NET SECTION IN ANGLES



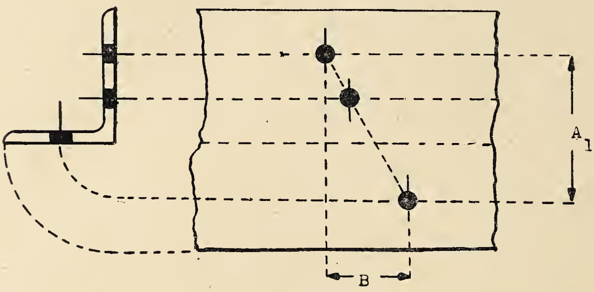
$Y = \text{diameter of rivet} + \frac{1}{8}''$.

$A - Y = \sqrt{A^2 + B^2} - 2\,Y$.

$A_1 - 2\,Y = \sqrt{A^2 + B^2} - 3\,Y$.

$B = \sqrt{2\,A\,Y + Y^2}$.

Cut 64.



Cut 63.

A = Sum of Gages minus the thickness of the angle.
$\frac{5}{8}''$ rivets can be taken at $\frac{1}{8}''$ less than for $\frac{3}{4}''$ rivets.
1″ rivets can be taken at $\frac{1}{8}''$ more than for $\frac{7}{8}''$ rivets.

A.	¾″ Rivet B.	⅞″ Rivet B.	A_1.	¾″ Rivet B.	⅞″ Rivet B.
1″	1⅝″	1¾″	5″	3 1/16″	3 5/16″
1½″	1⅞″	2″	5½″	3¼″	3½″
2″	2 1/16″	2¼″	6″	3⅜″	3⅝″
2½″	2¼″	2 7/16″	6½″	3½″	3¾″
3″	2 7/16″	2⅝″	7″	3⅝″	3⅞″
3½″	2 9/16″	2 13/16″	7½″	3¾″	4″
4″	2 13/16″	3″	8″	3⅞″	4⅛″
4½″	2 15/16″	3 3/16″	8½″	4″	4¼″

CHAPTER VIII

SHIP CONSTRUCTION

The shipyards in this country in the past have had to face the problem of turning out more vessels than they were ever designed to handle.

Due to the ravages of the U Boat in the world war the losses of ships amounted to approximately 30% of the world's merchant marine. The record of American Ship Yards in building ships amounted to some 340,000 tons dead weight, or approximately 280,000 tons gross weight per month. This activity on the part of the ship yards is illustrated well in the increase in the Plate rolling capacity in our steel mills and increased to meet the extraordinary demand. In 1916 we had a capacity of 125,000 tons of Steel plate per month, representing the total Ship plate production at that time, and four years from that time we have a capacity of 250,000 tons of ship plates per month or a doubling in four years.

The limit to shipbuilding in any ship yard is the ability of the auxiliary shops to machine and fabricate the materials entering into a ship, and of the handling equipment to move fabricated parts into their final place in the vessel. The number of riveters and other workers that can be placed at work on the actual ship is almost unlimited.

It was and to a certain extent is still common opinion that American shipyards cannot compete with those abroad in normal times on account of the difference in labor cost. Shipbuilding in England has been reduced to a manufacturing basis, the British shipyards specializing on types of vessels. One yard will build only Tugs, another only Oil Tankers, still another Bulk Freighters, while others specialize on Passenger Vessels and Battelships. Thus England taught us the lesson of single class ship building in the same yard, and we learned this lesson well. Normally we are hindered in maintaining selective manufacturing of ships, as Government work is not in harmony with standardized construction, and it is well that the Navy Department has enlarged some eight of its principal navy yards, which will thus permit of true manufacturing of Standard Vessels in our commercial yards.

In American Ship yards it was practice a few years ago to assemble the ship piece by piece in place within the hull. This was a slow process and is now superceded by modern methods of sub-asembly in the various fabricating shops of frames, bridges, bulkheads, deck structures, etc., these members being finally placed in the vessels in the completed condition. We have thus gone the Englishman one better, and ships now spend a much shorter time on the ways than formerly, and for this reason our permanent shipyards have greatly increased in capacity. Inside the yards selection of manufacture, and care in handling raw material, vis., classification of plates, shapes, and minor materials have aided in speeding up manufacture.

In the manufacture of ships an Oil Tanker requires more work, and hence a longer time on the ways than a Cargo Vessel, and Battleship longer than either of them. Roughly it requires 30 tons of plates for each 100 tons gross register of vessel capacity. A 10,000 ton ship will cost approximately $2,000,000 and of which expenditure $70,000 represents riveting.

It requires an average of 500,000 rivets to build the average Cargo Ship.

There are over 700,000 rivets in a 7500 ton vessel.

SHIP STEEL

Following are the Grades of Steel entering into Ship Construction as required by representative bureaus and concerns:

Requirements of..........	American Society Testing Materials	Navy Department.			Navy.	Navy.		AMERICAN BUREAU OF SHIPPING AMERICAN LLOYDS.					
For....................	Structural Steel for Ships.	Shapes, Plates, Soft	Medium	High Tensile	Common Steel.	Rivet. Medium.	High Tensile.	Ship Plates.	Ship Plates for Cold Flanging	Shapes.	Half Rounds and Half Ovals.	Rivet Bars	Manufactured Rivets.
Chemical:													
Phosphorous, Acid......	not over .060	.050	.050	.050	.....	....	....	....	....	....	....	....	
Phosphorous, Basic.....	" .040	.040	.040	.040	.....	.040	.040	....	....	....	....	....	See Note "D" below:
Sulphur...............	" .050	.050	.050	.050	.....	.040	.040	....	....	....	....	....	
							1.00. or more nickel						
Physical Tests:													
Tensile Strength........	58000 to 68000	50000	60000	80000	55000	58000—68000	75000—90000	58000—72000	58000—68000	58000—74000	No Test.	55000—67000	
Yield Point............	½ TS.	....	....	....	.....	....	....	½ TS.	½ TS.	½ TS.	No Test.	....	
Elongation in 8"........	1500000 ÷ T. S.	30%	25%	20%	22%	30%	25%	25%—20%	25%—22%	25%—22%	No Test.	25% ("C").	
Cold Bend..............	"A."	....	....	....	.....	....	....	"A." Marks. A.B.	"A." Marks. A.B./F.	"A." Marks. A.B.	No Test. Marks. A.B./B.	No Test.	
Number of tests per melt.												....	
Tension..............	1	....	....	....	.....	....	....	1 ("B")	1	1	....	1	
Bend..................	1	....	....	....	.....	....	....	1 ("B")	1	1	....	....	

"A." Bend 180° around a bar equal in diameter to test piece up to $\frac{3}{4}''$. Bend 180° around a bar equal in diameter to $1\frac{1}{2}$ times the thickness of the test piece for thickness of from $\frac{3}{4}''$ to $1\frac{1}{4}''$. Bend 180° around a bar equal in diameter to 2 times the thickness of the test piece for thickness over $1\frac{1}{4}''$. All to be accomplished without fracture on outside bent portion.

"B." In Bend Tests required by the American Bureau, one test for each melt is required unless the material from one melt differs $\frac{3}{8}''$ or more in thickness, when one bend and one tension test are required from both thickest and thinnest material rolled.

"C." The elongation required in Rivet Bars may also be a minimum of 31% on a length of $3\frac{1}{2}$ diameters. For material over $\frac{3}{4}''$ in thickness on other materials specified by the American Bureau, a deduction of 1 from the percentage of elongation specified shall be made for each increase of $\frac{1}{8}''$ in thickness above $\frac{3}{4}''$, to a minimum of 18%. The above values for elongation may also be expressed 1500000 ÷ TS.

"D." In testing Manufactured Rivets a sufficient number of sample rivets shall be taken, and must stand:—
Shank doubled together cold without fracture. Rivet head must stand flattening to a $2\frac{1}{2}$ times the diameter of the shank.

The maximum permissible variations in weight and gage of plate have been tabulated in the Section under Boilers, and the requirements as there given follow for Commercial Ship Plates. The Navy Department differ somewhat from these requirements, and for the knowledge necessary in this line of work, a tabulation of their allowable variations for Ship Plates is herewith given.

NAVY ALLOWANCE IN WEIGHT AND GAGE OF SHIP PLATES

Weight Ordered Lbs. Sq. Foot	Allowable Variation in weight. %. Over	under	Allowable under gage at edge %. Width of Plate. up to 40″	40″—50″	50″—60″	up to 60″	60″—70″	70″—80″	66″—80″	80″—90″	90″—100″	100″—110″	110″—120″
Up to 5 inc.	3	3	12	15	18	..	21	24	..	..	..	..	..
5 to 7½..	3	5	10	12	14	..	16	18	..	20	22	24	..
7½ to 10...	3	3	8	10	11	..	12	13	..	14	15	16	..
10 to 12½..	3	5	..	..	..	10	..	..	11	12	13	14	18
12½ to 15...	2	3	..	..	..	8	..	..	9	10	11	12	14
15 to 17½..	2	3	..	..	..	6	..	..	7	8	9	10	11
17½ to 20...	2	3	..	..	..	5	..	..	5	6	7	8	9
20 to 25...	2	3	..	..	..	4	..	..	5	5	3	6	7
25 to 30...	2	3	..	..	..	3	..	..	3	3	4	5	5
30 to 40...	2	3	..	..	..	3	..	..	3	3	3	3	4
40 and over	2	3	..	..	..	2	..	..	2	2	3	3	3

The Navy Departments requirements for Rivet Rod and for Manufactured Rivets naturally are most explicit, and a thorough understanding of them is of value commercially.

Rivet rods are tested by lots. A lot consists of all material rolled from an individual melt at a continuous rolling and grouped into sizes varying not more than ¼″ from the maximum to the minimum of the gages represented.

Two types of Test Bars are specified, numbered Type 1, and Type 3.

Type 1. Elongation measured in 2 inches.

Type 3. Elongation measured as follows:

Up to ¼″ diameter rod, measured in 2 inches.
Over ¼″ and to ½″ inclusive, in 4 inches.
Over ½″ and to ¾″ inclusive, in 6 inches.
Over ¾″ diameter rod, measured in 8 inches.

TESTS OF RIVET ROD

Tensile Tests:—Requirements were tabulated at the beginning of this section. Four tensile tests from each lot, unless the lot represents 2 tons or less, when two tests are sufficient.

Each test specimen shall be taken from a separate rod, and shall represent the maximum and the minimum gages in the lot, and if practical shall be taken from separate ingots.

All of the tests must meet the requirements given for the grade of steel represented, and no lot will be accepted if there is a difference of more than 8000 pounds per square inch in tensile strength between any of the specimens.

Bending Tests: Two bending tests shall be taken from each lot of medium steel. They shall bend cold 180° flat on themselves without cracking on outside bent portion. At the discretion of the Inspector bending tests for medium steel may be omitted.

Upsetting Tests: Test specimens 1¼ the diameter of the bar in length shall be taken, and four tests for each lot, but in no case less than three for each diameter of each melt.

High tensile shall stand hammering down cold to 60% of the original length, without showing seams or other defects.

Medium steel shall stand hammering down cold to 50% of the original length, without showing seams or other defects.

All tests shall be conducted on rods which have not been annealed or given special heat treatment.

Tolerances	up to ¼″ inc. , . .	Under 0.010 inch.
	Over ¼″ and to ½″ inc.	Under .014 inch.
	Over ½″ and to ¾″ inc.	Under .016 inch.
	Over ¾″ and to 1″ inc.	Under .020 inch.
	Over 1″ and to 1¼″ inc.	Under .024 inch.
	Over 1¼″.	Under .030 inch.

MANUFACTURED RIVETS

All rivets must be free from scale, fins, seams, rust, or other defects.

Medium Steel Rivets and Tap Rivets may be manufactured either in hot or cold heading machines up to ¾″ size; above ¾″ they shall be made by a hot heading machine.

High Tensile Rivets over ⅜″ in diameter shall be made hot headed. Rivets ⅜″ and under may be made by the cold heading process, provided the rivets are annealed after heading.

Tap Rivets must be milled under the head when made in a hot heading machine. When cold headed they will be accepted without being milled if the finish under the head is satisfactory.

TESTS ON MANUFACTURED RIVETS

Number of Tests:—6 rivets, taken at random, from each lot of rivets of each diameter presented for inspection.

Cold Tests:—3 rivets shall flatten cold to a thickness half the original diameter of the part flattened without showing cracks or flaws. Rivets over an inch in diameter shall flatten to three-quarter of the original diameter.

Hot Tests:—3 rivets shall flatten hot to a thickness not exceeding quarter the original diameter of the part flattened without cracks or flaws. These tests should be heated to the ordinary driving heat.

The above tests on Cold Headed Rivets shall be made after the rivets have been heated and air cooled.

Shearing Tests:—High tensile rivets shall be given a shearing test, from three rivets selected at random from each lot of each diameter. These rivets shall be driven hot for test under double shear. The shearing strength when so tested shall not be less than 64,000 pounds per square inch, figured from actual shearing area of the rivet as driven, vis, the area of the rivet hole.

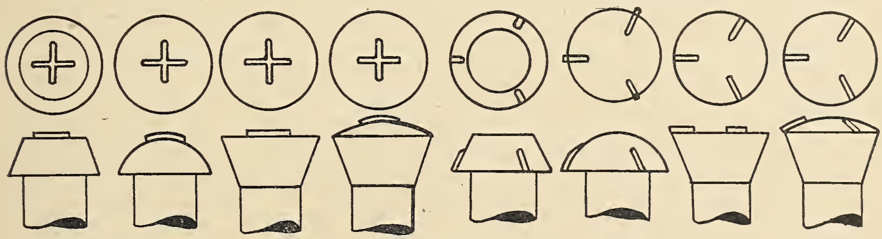
Navy rivets are marked with Grade marks as per the following figure. 72. Rivets may have the manufacturer's trade mark thereon subject to their not interfering with these grade marks, or with the efficiency of the rivets. These grade marks should not be used for rivets except for material for use of the Navy Department.

Rivets should be delivered in 100 pound or 200 pound boxes or kegs.

Medium Steel
Gross in Relief.

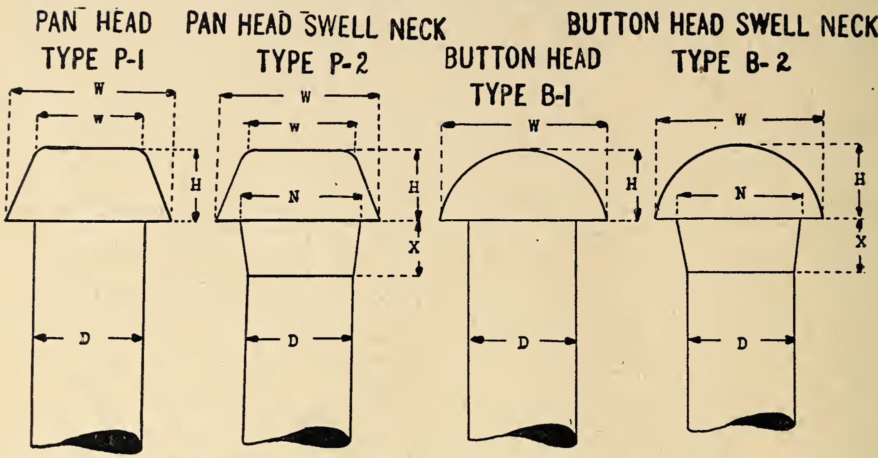
Proportions about as shown.
Projections about 1/32″.

High Tensile Steel
Flutes in Relief.
Proportions about as shown. Projections about 1/32″ to 1/16″. Those in Pan and Button Heads to taper to nothing at top; other heads no taper.



Cut 72.

STANDARD NAVY HEADS



PAN HEAD. P-1.	Diameter Shank D.	W.	w.	H.
	1/16″	7/16″	1/4″	3/16″
	3/8″	5/8″	3/8″	5/16″
	1/2″	13/16″	1/2″	3/8″
	5/8″	1″	5/8″	7/16″
	3/4″	1 3/16″	3/4″	1/2″
	7/8″	1 5/16″	7/8″	9/16″
	1″	1 1/2″	1″	5/8″
	1 1/8″	1 5/8″	1 1/8″	11/16″
	1 1/4″	1 13/16″	1 1/4″	3/4″

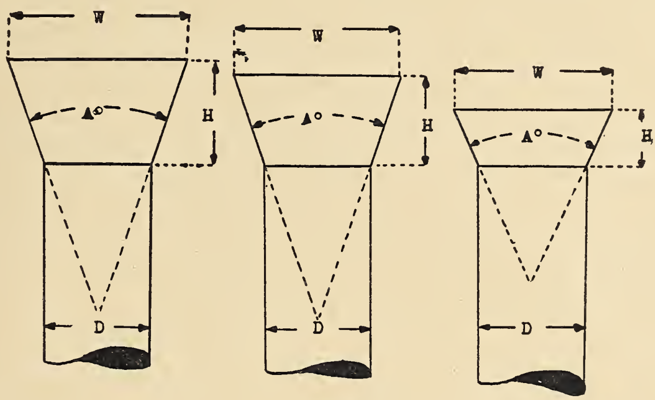
PAN HEAD SWELL NECK. P-2.	Dia. Shank D.	W.	w.	N.	H.	X.
	1/2″	13/16″	1/2″	9/16″	3/8″	1/4″
	5/8″	1″	5/8″	11/16″	7/16″	5/16″
	3/4″	1 3/16″	3/4″	13/16″	1/2″	3/8″
	7/8″	1 5/16″	7/8″	15/16″	9/16″	7/16″
	1″	1 1/2″	1″	1 1/16″	5/8″	1/2″
	1 1/8″	1 5/8″	1 1/8″	1 3/16″	11/16″	9/16″
	1 1/4″	1 13/16″	1 1/4″	1 5/16″	3/4″	5/8″

BUTTON HEAD. B-1.	Diameter Shank D.	W.	H.
	1/4″	7/16″	3/16″
	3/8″	5/8″	5/16″
	1/2″	13/16″	3/8″
	5/8″	1″	7/16″
	3/4″	1 3/16″	1/2″
	7/8″	1 5/16″	9/16″
	1″	1 1/2″	5/8″
	1 1/8″	1 5/8″	11/16″
	1 1/4″	1 13/16″	3/4″

BUTTON HEAD SWELL NECK. B-2	Diameter Shank. D.	W.	N.	H.	X.
	½″	$\frac{13}{16}$″	$\frac{9}{16}$″	⅜″	¼″
	⅝″	1″	$\frac{11}{16}$″	$\frac{7}{16}$″	$\frac{5}{16}$″
	¾″	1$\frac{3}{16}$″	$\frac{13}{16}$″	½″	⅜″
	⅞″	1$\frac{5}{16}$″	$\frac{15}{16}$″	$\frac{9}{16}$″	$\frac{7}{16}$″
	1″	1½″	1$\frac{1}{16}$″	⅝″	½″
	1⅛″	1⅝″	1$\frac{3}{16}$″	$\frac{11}{16}$″	$\frac{9}{16}$″
	1¼″	1$\frac{13}{16}$″	1$\frac{5}{16}$″	¾″	⅝″

STANDARD NAVY HEADS
Countersunk Flat Heads

Type C-1 Type C-2 Type C-3



Cut 74.

COUNTERSUNK FLAT HEAD. C-1.	Diameter Shank. D.	W.	H.	Angle A°.
	¼″	⅜″	$\frac{3}{32}$″	60°
	⅜″	⅝″	$\frac{7}{32}$″	60°
	½″	$\frac{13}{16}$″	¼″	60°
	⅝″	1$\frac{1}{16}$″	⅜″	60°
	¾″	1$\frac{5}{32}$″	½″	45°
	⅞″	1$\frac{7}{16}$″	$\frac{11}{16}$″	45°
	1″	1⅝″	$\frac{15}{16}$″	37°
	1⅛″	1¾″	$\frac{15}{16}$″	37°
	1¼″	1$\frac{29}{32}$″	1″	37°

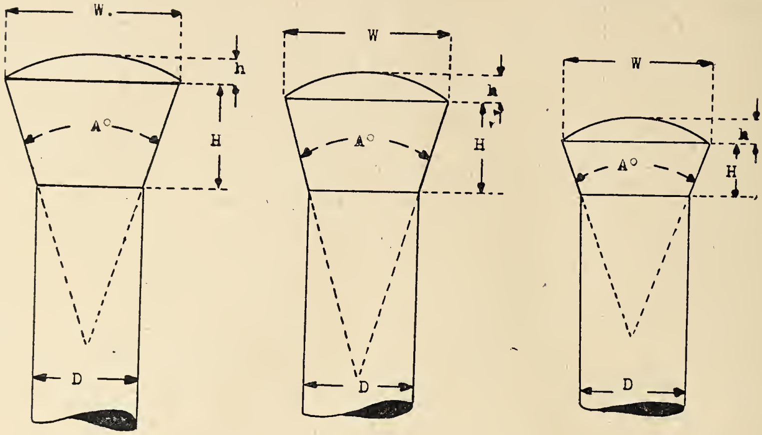
COUNTERSUNK FLAT HEAD. C-2.	Diameter Shank D.	W.	H.	Angle A°
	⅝″	$\frac{15}{16}$″	$\frac{9}{32}$″	60°
	¾″	1$\frac{1}{16}$″	⅜″	45°
	⅞″	1$\frac{11}{32}$″	$\frac{9}{16}$″	45°
	1″	1$\frac{17}{32}$″	$\frac{13}{16}$″	37°

COUNTERSUNK FLAT HEAD. C-3.	Diameter Shank. D.	W.	H.	Angle A°
	⅞″	1¼″	$\frac{7}{16}$″	45°
	1″	1$\frac{13}{32}$″	½″	45°
	1⅛″	1$\frac{9}{16}$″	⅝″	37°
	1¼″	1¾″	¾″	37°

STANDARD NAVY HEADS

Countersunk Raised Heads

Type CR-1 Type CR-2 Type CR-3



Cut 75.

COUNTERSUNK RAISED HEAD.	Diameter Shank. D.	W.	h.	H.	Angle A°
CR-1.	1/4″	3/8″	1/16″	5/32″	60°
	3/8″	5/8″	3/32″	7/32″	60°
	1/2″	13/16″	1/8″	1/4″	60°
	5/8″	1 1/16″	5/32″	3/8″	60°
	3/4″	1 5/32″	3/16″	1/2″	45°
	7/8″	1 7/16″	7/32″	11/16″	45°
	1″	1 5/8″	1/4″	15/16″	37°
	1 1/8″	1 3/4″	9/32″	15/16″	37°
	1 1/4″	1 29/32″	5/16″	1″	37°

COUNTERSUNK RAISED HEAD.	Diameter Shank. D.	W.	h.	H.	Angle A°
CR-2.	5/8″	15/16″	5/32″	9/32″	60°
	3/4″	1 1/16″	3/16″	3/8″	45°
	7/8″	1 11/32″	7/32″	9/16″	45°
	1″	1 17/32″	1/4″	13/16″	37°

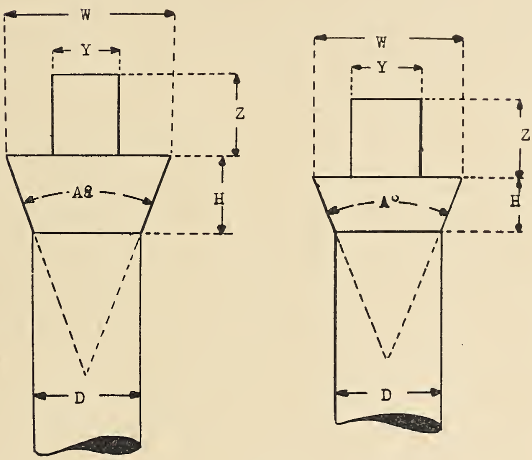
COUNTERSUNK RAISED HEAD.	Diameter Shank. D.	W.	h.	H.	Angle A°
CR-3.	7/8″	1 1/4″	7/32″	7/16″	45°
	1″	1 15/32″	1/4″	1/2″	45°
	1 1/8″	1 9/16″	9/32″	5/8″	37°
	1 1/4″	1 3/4″	5/16″	3/4″	37°

NOTE.—Angles and Depths "H," are to be followed. Diameters given are approximate

NAVY STANDARD HEADS

Tap Rivets

Type T-1 Type T-2



Cut 76.

TAP RIVETS.	Dia. Shank. D.	W.	Y.	Z.	H.	Angle A°
T-1.	1/2"	23/32"	3/8" square	1/2"	3/16"	60°
	5/8"	29/32"	7/16" "	5/8"	1/4"	60°
	3/4"	1 1/8"	1/2" "	23/32"	5/16"	60°
	7/8"	1 1/4"	9/16" "	23/32"	7/16"	45°
	1"	1 19/32"	3/8" "	23/32"	11/16"	45°
	1 1/8"	1 5/8"	5/8 "	23/32"	3/4"	37°
	1 1/4"	1 27/32"	11/16" "	23/32"	7/8"	37°

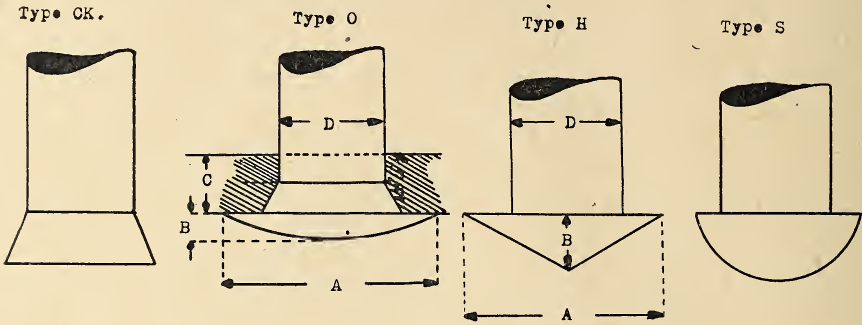
TAP RIVETS.	Dia. Shank. D.	W.	Y.	Z.	H.	Angle A°
T-2.	7/8"	1 1/8"	9/16" square.	23/32"	5/16"	45°
	1"	1 13/32"	5/8" "	23/32"	1/2"	45°

All Tap Rivets should have U. S. Standard Threads.

Outside Diameter.	Root Diameter.	Threads per inch.
1/2"	.400	13
5/8"	.507	11
3/4"	.620	10
7/8"	.731	9
1"	.837	8
1 1/8"	.940	7
1 1/4"	1.065	7

NAVY STANDARD HEADS
Rivet Points

Type.	Form.	Proportions.
CK	Countersunk.....	Same as for Countersunk Heads.
O	Oval Liverpool...	A = 2 D B = ¼ D Countersunk = ½ C.
H	Hammered......	A = 1¾ D B = ½ D.
S	Snap............	Same as for Button Heads.



Cut 77.

Rivets of different formed heads are used in different construction in a vessel, and the following table indicates the use of different heads and points.

TYPE OF HEAD.	WHERE USED
PAN HEAD.	In general work, except where other types are permitted or required.
BUTTON HEAD.	In casings, etc., where required for finished appearance, and when approved to suit types of Power Riveting Machines employed.
COUNTERSUNK HEADS.	Where flush surfaces are required. In staple and boundary bars, etc., where oil or water tightness is required and where heads of rivets may require calking.
SWELL NECKS.	In all work with pan or button head rivets ½″ diameter or over, except where otherwise approved.
COUNTERSUNK POINTS.	Where flush surfaces are required and where the rivet point may require calking. In outside plating, these points shall generally be used, and formed so that while not forming a distinct projection they shall be full enough to hold a straight edge off the surface of the material.
SNAP POINTS.	In framing and structural work generally, where flush work is not required. In sheer strakes of outside plating, where strength is required, in order to avoid less of material by countersinking.
HAMMERED POINTS.	Where specially approved or specified.
OVAL POINTS.	In exposed finished surfaces with material less than 7½ pounds per square foot, where watertightness under pressure is not required.
TAP RIVETS.	In connections of plates and shapes to castings, forgings, and to armour, and other material where through rivets are not practical. These rivets may also be used as through rivets for attachments to outside of shell plating where the plating is over 15 pounds per square foot, in this case it shall be tapped into the plating and set up on the inside with nut, washer and gremmet.

The S. Severance Manufacturing Company will furnish unless otherwise specified Pan Head Rivets and Pan Head Swell Neck Rivets in accordance with the U. S. Navy Specifications, of Types P-1, and P-2, respectively.

ALLOWANCE FOR POINTS IN LENGTHS OF RIVETS

Two Thicknesses Connected

If more than two thicknesses are connected, for each additional thickness $\frac{1}{8}''$ should be added.

Type of Point.	Diameter of Rivet.					
	½″	⅝″	¾″	⅞″	1″	1⅛″
Countersunk...	½	⅝	¾	⅞	1	1⅛
Hammered....	½	½	½	⅝	⅝	⅝
Snap..........	⅞	1	1⅛	1¼	1⅜	1½
Oval..........	⅞	⅞	....	....	....	....

In the following much description of riveting in different parts of a ship will be given, and the following brief summary of the important parts of a vessel are given for general information.

Composition of a Hull

A. A Frame has three parts:
   1. Frame bar, outer angle.
   2. Reverse bar, or inner angle.
   3. Floor plate connecting the frame bar and reverse bar.

B. The Keel to which the frames are secured by the first strake of outside plating known as the garbord strake. There are several types of keel.
   1. Bar keel.
   2. Side Bar keel.
   3. Flat Plate keel.

C. Keelsons lying above the floor plate and on top of the Reverse bar or frame, and is a longitudinal girder parallel to the keel. All longitudinal girders on the bottom of a ship are keelsons, some intercostal, or between frames, others continuous for the length of the ship, such as bilge keelsons, etc.

D. Deck beams connect the legs of frames across the ship, brackets or knees being the binding plates at the connection.

E. Longitudinal deck stringers cross the beams in the lengthwise direction of the ship.

F. At the stem and stern of the ship, triangular pieces called breasthooks connect the stringers. The continuation of the keel and keelsons at the bow of the ship form the stem, while their continuation to the rudder post form the vertical termination at the stern.

G. Outside plating is riveted to the frames, and the adjoining plates to each other. There are several methods of lapping the plates.
   1. In and Out system. Outside strakes lapping alternately over the inner strakes of plating.
   2. Clinker system. Plates overlapping one above the other not alternately.
   3. Flush outer surface obtained by doubling the inner strakes and forming butt joints on the outside plating called doubling.

THE OPERATIONS IN FABRICATING A SHIP

1. A wooden template or mold is made in the mold loft, of wooden strips, and shaped to the plate as shown on the drawings. Care must be taken in the making of this template, every twist and curve being shown, and every rivet hole properly set out.

2. The ship fitter clamps the above template to the plate, which as previously indicated, are sorted and classified in the storage yard. Laying Out the plate or shape for punching. Every rivet hole must be properly center punched and often "horse shoed" or circled with paint to indicate the location. The shear edges are carefully indicated.

3. The holes are punched as indicated, the speed of modern punching machines being very great, or drilled as specified. Plate is sheared, and shapes bent hot to the required curvitures. If much furnacing is done, or severe bending cold is done, annealing must be done after these operations.

4. Assembly of the fabricated pieces in the Ship frame. The plates and sub-assembled shapes are clamped into position and bolted to the next member. In plate work it is sometimes difficult to get a complete fit. Creaping of plates and similar problems are perplexing to the shipbuilder, due to the long curved surfaces on which work is being performed. The Laying Out is not always as accurate as desired, although the Layer Out has conscientiously done his work, and the other operators have done likewise. The ideal situation is one where every plate becomes a "closer." Ordinarily much reaming of matched holes is necessary, not all of the holes coming fair.

5. Riveting became of public interest during the war period, and the riveter became a guide to the efficiency of the various shipyards doing emergency work. Many riveting contests were held in the various shipyards, and rivalry once started was keen. Much misconception exists on the records made in driving rivets. One team on the Pacific Coast drove an average of 687 rivets per day for 26 consecutive days of a month, these being driven in all parts of the ship. A 1000 iivets driven per day with the usual three man gang is not uncommon for certain parts of a ship, particularly the hull, but 400 rivets per day per gang, for average conditions for all gangs is probably more nearly correct.

The call for riveters was naturally the first cry of the shipbuilder when the pressure of work became acute, and a school for the instruction of riveters was started at Newport News. The idea used was novel, skilled craftsmen being instructed how to instruct others, these men, after a period of six weeks' instruction at the school, going out to different yards and conducting schools themselves. Thus innumerable riveters for ship work were made from our supply of bridge builders, structural iron workers, etc.

The compensation paid riveters varied, but the following can be taken as representative, the compensation being paid piece rate. In a riveting gang of three men:

Riveter received from $1.76 to $2.64 per 100 rivets.
Bucker Up (Holderon) $1.32 to $1.98 per 100 rivets.
Heater..............$ .92 to $1.38 per 100 rivets.

Thus the driving of rivets, figured from sound rivets driven, cost in the neighborhood of $6.00 per 100 driven, and for a ship containing 500,000 rivets would be $30,000.

1. Machine riveting done with Pneumatic hammers.

2. Pressure riveting done with a Hydraulic or Lever Pneumatic machine, usually in assembly shops or sub-assemblies.

3. Hand riveting on special positions.

6. Every rivet driven is tested. A rivet tapper holds his finger on the rivet head and taps the driven head with a light hammer. If he feels the jar the rivet is loose and must be cut out. Burned rivets are detected by the appearance of the head. Loose and burned rivets, and off center heads must be cut out and replaced.

A rivet cutting gun has come into prominence in affecting this cutting, the head being busted off, and the rivet backed out with a specially pointed tool. A safety device prevents the flying of the cut off head. With the use of this apparatus as many as 10 $\frac{7}{8}''$ rivets can be cut and backed out per minute. In driving out countersunk rivets that have been condemned, the gun drives through the countersink, the countersink head coming off in the form of a ring. $1\frac{1}{4}''$ countersunk rivets have been cut out at the rate of six per minute. A crew of three men have cut out as many as 6000 rivets in an eight-hour day, such work however being done on a number of vessels.

A Pneumatic hammer also is modified to form a rivet cutter, and it was practice to burn off defective heads with a cutting torch, one being devised that gives a flame parallel to the plating. There is a tendency to weld the rivet in the hole and to damage to the plate when using a torch.

Probably no profession requires the extent of detail that Ship construction does, and the foregoing is only a very brief description of the principal operations, dwelling necessarily on our subject of Riveting.

In order to furnish information of value to the actual shipbuilder the following requirements for Naval and commercial work are given, the Naval requirements being those of the U. S. Navy Department for Riveting, and the commercial as required by the American Bureau of Shipping.

General Requirements U. S. Navy on Riveting

Rivets connecting medium steel parts may be medium steel.

Rivets connecting high tensile steel parts, where strength is of special consideration, shall be high tensile steel.

Where high tensile steel plating is connected to medium steel beams and frames, where strength is not of special consideration, medium steel rivets may be used.

Where plates of different thickness are connected together, the size of the rivet and the spacing shall be as for the thicker plate, where strength is required.

When water tightness or oil tightness is required, the size of the rivet and the spacing shall be as for the thinner plate.

If the thinner plates is half or less than the thicker plate, the rivet used shall be of intermediate size.

Where plates and shapes connect the size and spacing of the rivets shall in general correspond to the thickness of the plate.

Through rivets in stems, sternposts and heavy castings shall be $\frac{1}{8}''$ larger than required for the plates connected to them.

For Three-ply and Four-ply work the riveting may be $\frac{1}{8}''$ larger than normal, in order to facilitate the drawing together of the plates. Exception is made to double strapped butt joints.

In Double Strapped Butt Joints, where plating connected is 25 pounds or less, the rivets shall be one size smaller than normal.

Tap Rivets shall be $\frac{1}{8}''$ larger than the ordinary rivets required for the material in which the contersink occurs. Taps into heavy castings and forgings shall be $\frac{1}{4}''$ larger.

TYPE OF RIVETING

Connection.	Plate Weight.	Riveting.
Single Butt Straps...	Under 7½ pounds............	Single row.
	7½ and under 15..............	Double row.
	15 and under 25..............	Triple row.
Butt Laps..........	25 and under 35..............	Quadruple row.
	35 and under 50..............	Quintiple row.
Double Butt Straps...	15 and under 20..............	Double row either side of joint.
	20 and under 30..............	Triple row " " "
	30 and under 50..............	Quadruple row" " "

Chain Riveting shall be used generally where two or more rows of rivets are required in butts and seams of plating.

Zigzag Riveting shall be used in shapes where two or more rows are required. In vessels of specially light construction in general Zigzag riveting is used in butts and seams of plating.

The distance from center to center of rows of Chain Riveting in seams and single butt straps shall not be less than $2\frac{1}{2}$ diameters. In butt laps and double butt straps it shall not be less than 3 diameters of the rivet.

In Zigzag Riveting of plates, straps and shapes generally the distance between centers of rows shall not be less than:

$3\frac{1}{2}$ in rows, $1\frac{1}{2}$ diameters.
4 in rows, $1\frac{3}{4}$ diameters.
$4\frac{1}{2}$ in rows, $1\frac{7}{8}$ diameters.
5 in rows, $1\frac{7}{8}$ diameters.
$5\frac{1}{2}$ in rows, 2 diameters.
6 in rows, 2 diameters.

Centers of rivets shall not be less than $1\frac{5}{8}$ diameters from the edge of plates or straps. This likewise follows for angles or shapes, except where a calking edge is obtained in angles by chipping, when the distance from the center of the rivet to the edge may be $1\frac{1}{2}$ diameters.

STRAPS

Single butt and seam straps, when single and double riveted, shall be of the same thickness of the plates connected.

Single butt straps, when triple riveted or over, shall be at least 1.2 times the thickness of the plates connected.

Double straps where double riveted shall each be half the thickness of the plates connected.

Double straps where triple riveted or over, shall each be $\frac{5}{8}$ times the thickness of the plate.

Where rivet holes in ordinary double riveted double strapped joints are countersunk, the weight of the contersunk straps shall be increased to 5/8 times the thickness of the plate, to compensate for the loss of material.

Where plates of different thickness are connected the thickness of the butt strap shall be governed by the lighter plate.

PROPORTIONS OF JOINTS—Laps and Straps—Chain Riveting

Weight Plate =		Under 3	3 to 7	7 to 8 1/2	8 1/2 to 12 1/2	12 1/2 to 19	19 to 29	29 to 39	39 to 49	Over 49	Width of Connection in rivet diameters
Rivets, inches	....	1/4	3/8	1/2	5/8	3/4	7/8	1"	1 1/8	1 1/4	
Rivet Hole	....	9/32	13/32	9/16	11/16	13/16	15/16	1 1/16	1 3/16	1 5/16	
Area Hole, sq. in.	....	.062	.130	.248	.371	.518	.690	.887	1.107	1.353	
Connection.	Riveting.	Width of Connection in inches.									
Seam Laps	1	13/16	1 1/4	1 5/8	2 1/16	2 7/16	2 7/8	3 1/4	3 11/16	4 1/16	3 1/4
	2	1 7/16	2 3/16	2 7/8	3 5/8	4 5/16	5 1/16	5 3/4	6 1/2	7 3/16	5 3/4
	3	...	...	...	...	6 3/16	7 1/4	8 1/4	9 5/16	10 5/16	8 1/4
Butt Laps	2	1 9/16	2 3/8	3 1/8	3 15/16	4 11/16	5 1/2	6 1/4	7 1/16	7 13/16	6 1/4
	3	...	...	4 5/8	5 13/16	6 15/16	8 1/8	9 1/4	10 7/16	11 9/16	9 1/4
	4	...	...	...	...	9 3/16	10 3/4	12 1/4	13 13/16	15 5/16	12 1/4
Seam and Butt straps, single	1	1 5/8	2 7/16	3 1/4	4 1/16	4 7/8	5 11/16	6 1/2	7 5/16	8 1/8	6 1/2
	2	2 7/8	4 5/16	5 3/4	7 3/16	8 5/8	10 1/16	11 1/2	12 15/16	14 3/8	11 1/2
	3	...	...	8 1/4	10 5/16	12 3/8	14 7/16	16 1/2	18 9/16	20 5/8	16 1/2
	4	...	...	...	...	16 1/8	18 13/16	21 1/2	24 3/16	26 7/8	21 1/2
	5	...	...	...	...	19 7/8	23 3/16	26 1/2	29 13/16	33 1/8	26 1/2

NOTE:—1 = Single riveting, 2 = Double riveting, etc.

LAPS AND STRAPS—Zigzag Riveting

Weight Plate =	....	Under 3	3 to 7	7 to 8 1/2	8 1/2 to 12 1/2	12 1/2 to 19	19 to 29	Width of Connection in rivet diameters
Rivets, inches	....	1/4	3/8	1/2	5/8	3/4	7/8	
Rivet Hole	....	9/32	13/32	9/16	11/16	13/16	15/16	
Area Hole, sq. in.	....	.062	.130	.248	.371	.518	.690	
Connection.	Riveting.	Width of Connection in inches.						
Seam Laps, Double Riveting.	3 1/2 d	1 3/16	1 13/16	2 3/8	3	3 9/16	4 3/16	4 3/4
	4 d	1 1/4	1 7/8	2 1/2	3 1/8	3 3/4	4 3/8	5
	4 1/2 d	1 9/32	1 15/16	2 9/16	3 1/4	3 7/8	4 1/2	5 1/8
Single Straps, Double Riveting.	3 1/2 d	2 3/8	3 9/16	4 3/4	5 15/16	7 1/8	8 5/16	9 1/2
	4 d	2 1/2	3 3/4	5	6 1/4	7 1/2	8 3/4	10
	4 1/2 d	2 9/16	3 7/8	5 1/8	6 7/16	7 11/16	9	10 1/4

PUNCHING AND DRILLING OF PLATE

Table of Requirements for Different Classes of Work

A. = Where subject to testing for Oil tightness.
B. = Where strength is of special importance.
C. = In three or more thicknesses of material.
D. = Holes punched, and not included in A. B. C.

Weight of Plate, Pounds.	Holes Punched. Work on A. B. C.				Holes Punched. Work on D. above.			Holes drilled, not in place, small, then reamed.		Holes drilled full size in place.
	Rivet.	Punch.	Die.	Reamer.	Punch.	Die.	Reamer.	Drill	Reamer.	Drill.
Up to 3	$\frac{1}{4}''$	$\frac{7}{32}''$	$\frac{1}{4}''$	$\frac{9}{32}''$	$\frac{1}{4}''$	$\frac{9}{32}''$	$\frac{9}{32}''$	$\frac{1}{4}''$	$\frac{9}{32}''$	$\frac{9}{32}''$
3 to 6	$\frac{3}{8}''$	$\frac{11}{32}''$	$\frac{3}{8}''$	$\frac{13}{32}''$	$\frac{3}{8}''$	$\frac{13}{32}''$	$\frac{13}{32}''$	$\frac{3}{8}''$	$\frac{13}{32}''$	$\frac{13}{32}''$
6 to $8\frac{1}{2}$	$\frac{1}{2}''$	$\frac{7}{16}''$	$\frac{1}{2}''$	$\frac{9}{16}''$	$\frac{1}{2}''$	$\frac{9}{16}''$	$\frac{9}{16}''$	$\frac{1}{2}''$	$\frac{9}{16}''$	$\frac{9}{16}''$
$8\frac{1}{2}$ to $12\frac{1}{2}$	$\frac{5}{8}''$	$\frac{9}{16}''$	$\frac{5}{8}''$	$\frac{11}{16}''$	$\frac{5}{8}''$	$\frac{11}{16}''$	$\frac{11}{16}''$	$\frac{5}{8}''$	$\frac{11}{16}''$	$\frac{11}{16}''$
$12\frac{1}{2}$ to 19	$\frac{3}{4}''$	$\frac{11}{16}''$	$\frac{3}{4}''$	$\frac{13}{16}''$	$\frac{3}{4}''$	$\frac{13}{16}''$	$\frac{13}{16}''$	$\frac{3}{4}''$	$\frac{13}{16}''$	$\frac{13}{16}''$
19 to 29	$\frac{7}{8}''$	$\frac{13}{16}''$	$\frac{7}{8}''$	$\frac{15}{16}''$	$\frac{7}{8}''$	$\frac{15}{16}''$	$\frac{15}{16}''$	$\frac{7}{8}''$	$\frac{15}{16}''$	$\frac{15}{16}''$
29 to 39	$1''$	$\frac{15}{16}''$	$1''$	$1\frac{1}{16}''$	$1''$	$1\frac{1}{16}''$	$1\frac{1}{16}''$	$1''$	$1\frac{1}{16}''$	$1\frac{1}{16}''$
39 to 49	$1\frac{1}{8}''$	$1\frac{1}{16}''$	$1\frac{1}{8}''$	$1\frac{3}{16}''$	$1\frac{1}{8}''$	$1\frac{3}{16}''$	$1\frac{3}{16}''$	$1\frac{1}{8}''$	$1\frac{3}{16}''$	$1\frac{3}{16}''$
Over 49	$1\frac{1}{4}''$	$1\frac{3}{16}''$	$1\frac{1}{4}''$	$1\frac{5}{16}''$	$1\frac{1}{4}''$	$1\frac{5}{16}''$	$1\frac{5}{16}''$	$1\frac{1}{4}''$	$1\frac{5}{16}''$	$1\frac{5}{16}''$

In plates and shapes corresponding to a weight of $12\frac{1}{2}$ pounds per square foot and less, the depth of countersink may be full thickness of the material.

In plates and shapes of greater thickness the depth of countersink shall be approximately $\frac{1}{16}''$ less than the thickness of the material.

Where countersinking in accordance with the above is not suitable for one of the standard heads of rivets, it shall be made to suit, the nearest standard depth of rivet head. In no case, shall the depth of the countersink be such that the head of the rivet before driving is less than approximately $\frac{1}{16}''$ above the surface of the plate or shape. The head must not be below the surface of the plate or shape after driving.

Where rivets of the raised countersink type are to be used the angle or countersink for the holes, may if desired, be increased 3° over the standard angle for the head of the rivet.

DOUBLE BUTT STRAPS

Chain Riveting

Weight Plate =	12½–19	19 to 25	25 to 29	29 to 39	39 to 49	Over 49	Width in rivet diam'trs
Rivet, inches	⅝	¾	⅞	1″	1⅛″	1¼″	....
Rivet holes	$\frac{11}{16}$	$\frac{13}{16}$	$\frac{15}{16}$	$1\frac{1}{16}$	$1\frac{3}{16}$	$1\frac{5}{16}$	....
Area holes	.371	.518	.690	.887	1.107	1.353	....
Riveting.	Width of Straps, inches.						
Double	$7\frac{13}{16}$	9⅜	$10\frac{15}{16}$	12½	$14\frac{1}{16}$	15⅝	12½
Triple	$11\frac{9}{16}$	13⅞	$16\frac{3}{16}$	18½	$20\frac{13}{16}$	23⅛	18½
Quadruple	$15\frac{5}{16}$	18⅜	$21\frac{7}{16}$	24½	$27\frac{9}{16}$	30⅝	24½

DRILLS AND TAPS FOR TAP RIVETS

Tap Rivet.	Tap Drill.	Tap Threads per inch. U. S. Standard.
⅜	$\frac{5}{16}$	16
½	$\frac{27}{64}$	13
⅝	$\frac{33}{64}$	11
¾	$\frac{41}{64}$	10
⅞	¾	9
1″	$\frac{55}{64}$	8
1⅛	$\frac{61}{64}$	7
1¼	$1\frac{3}{32}$	7

Centers of taps from the edge of the plate or shape should not be less than the distance required by a rivet of ⅛″ less size than the tap. Where taps are ¼″ larger than the rivets that they substituted, the distance in general should be 1⅝ diameters from the edge.

PREPARATION OF WORK

Faying surfaces of all plates and shapes shall be carefully cleaned just before the work is assembled.

Faying surfaces of non-watertight work shall be painted, except in drinking water, fuel oil, and lubricating oil tanks.

Stop waters shall not be used to make good defective workmanship or materials, nor where the best practice requires metal to metal contact.

Stop waters shall be used in general only where non-watertight members pass through water-tight members.

Stop waters may be of canvas or lampwicking soaked in a mixture of red and white lead, or may be soaked in boiled linseed oil and then in red lead paint.

Oil stops shall be used under similar conditions to stop waters, where the material is over 7½ pounds, and only where metal to metal calking is not practical. Oil stops may be used in seams, laps, stapling, etc., when necessary to secure oil tightness in material of 7½ pounds or less.

Oil stops for material over $7\frac{1}{2}$ pounds, may be lampwicking or canvas thoroughly saturated with red lead and shellac mixture, or soaked in a mixture of pine tar and shellac. Oil stops for material $7\frac{1}{2}$ pounds and less shall be of 10 ounce canvas soaked for half day in clear shellac and then coated with red lead and shellac mixture, or the mixture of pine tar and shellac.

Work shall in all cases be carefully closed up by bolting before riveting is commenced.

Generally in oil-tight work, one bolt must be fitted for every four rivet holes.

All burrs and chips shall be removed, and buckles and lumps shall be faired out before riveting is done.

The rivets shall be properly proportioned for the holes and of sufficient length to insure a satisfactory point.

Such cutting of the rivets shank as may be necessary should be done while the rivets are at a dull red heat.

Rivet points are to be left full and must not finish below the surface of the material.

Care should be taken not to burn rivets in heating. Burnt rivets shall be cut out and replaced.

In oil-tight work all rivets, as far as practical, should be power driven, and all power driven rivets should be bucked up by a power operated holder on.

All rivet points shall be of adequate strength and properly centered.

Snap points shall not be reduced in standard size through using tools that have been ground down below these sizes, or that are otherwise imperfect.

Rivets less than $\frac{3}{8}''$ in diameter may be driven cold, and when used in watertight work, stop waters shall be fitted to secure tightness.

All rivets driven shall be tested. Loose, burned, eccentric pointed rivets and those with heads standing off from the surface shall be cut out and replaced.

COMMERCIAL OR MERCHANT MARINE REQUIREMENTS

Abstracts from the American Bureau of Shipping Requirements, and Lloyd's.

The American Bureau of Shipping, commonly referred to as "American Lloyds," issues rules for the construction of Steel vessels. Compliance with these rules are necessary. As far as rivets and riveting are concerned the following may be considered as representative.

In the following table on riveting, attention is invited to the thickness of plate controlling the rivet size, and the use and spacing of different sizes of rivets in the construction of a steel vessel.

RIVETING

SPACING AND SIZES ARE GIVEN IN INCHES

THICKNESS OF PLATE	·18*-·20	·22*-·24	·26-·30	·32-·34	·36-·38	·40-·42	·44-·48	·50-·52	·54-·58	·60-·64	66-·68	·70-·74	·76-·80	·82-·84	·86-·88	·90-·98	1·00-1·06	1·08-1·12	1·14-1·26	1·28-1·38
SIZE OF RIVET	5/8	5/8	5/8	5/8	3/4	3/4	3/4	7/8	7/8	7/8	7/8	1	1	1	1	1 1/8	1 1/8	1 1/8	1 1/4	1 3/8
Diameter of Countersink Face	1	1	1	1	1 3/16	1 3/16	1 3/16	1 5/16	1 5/16	1 5/16	1 6/16	1 9/16	1 9/16	1 9/16	1 9/16	1 12/16	1 12/16	1 12/16	1 15/16	2 3/16
Oiltight Seams and Butts; Spacing	2	2	2¼	2¼	2¾	2¾	2¾	3¼	3¼	3¼	3¼	3¾	3¾	3¾	3¾	4¼	4¼	4¼	4¾	5¼
Tank and Girder Butts; Watertight Seams; Engine and Thrust Seat Plates; Spacing	2½	2½	2¾	2¾	3⅜	3⅜	3⅜	4	4	4	4	4½	4½	4½	4½	5¼	5¼	5¼	6	6½
Sheerstrake, Topside Strake and Strength Deck; Riveting in Butts	Single	Double	Double	Double	Double	Treble	Treble	Treble	Treble	Quad'le	Quad'le	Quad'le	Quad'le	Quin'ple	Quin'ple	Quin'ple	Quin'ple	Quin'ple	Quin'ple	Quin'ple
Sheerstrake, Topside Strake and Strength Deck Amidships; Spacing in Butts	2¼	2¼	2¼	2¼	3	3	3	4	4 and 3	4	4 and 3	4½	4½ and 3½	4½	4½ and 3½	5¼	5¼ and 4¼	5¼ and 4¼	6 and 5	6½ and 5½
Shell and Other Plates Amidships; Riveting in Butts	Single	Double	Double	Double	Double	Double	Treble	Treble	Treble	Treble	Quad'le	Quad'le	Quad'le	Quad'le	Quad'le	Quad'le	Quad'le	Quad'le	Quad'le	Quad'le
Shell and Other Plates Amidships; Spacing in Butts	2¼	2¼	2¼	2¼	3	3	3	4	4	4 and 3	4	4½	4½	4½ and 3½	4½ and 3½	5¼	5¼ and 4¼	5¼ and 4¼	6 and 5	6½ and 5½
Butts at Ends, and Seams at Breaks of Superstructure; Riveting	Single	Single	Single	Double	Double	Double	Double	Treble	Treble	Treble	Treble	Treble	Treble	Treble	Treble	Treble	Treble	Treble	Treble	Treble
Butts at Ends, and Seams at Breaks of Superstructure; Spacing	2¼	2¼	2¼	2¼	3	3	3	4	4	4	4	4	4	4	4	4¼	4¼	4¼	4¾	5¼
Masts, Keel Angles; Floor Connecting Angles; Edges of Doubling Plates; Brackets; Shell Clips in Peaks; Spacing in Zig-zag Seams and in Butts and Seams	3⅛	3⅛	3⅛	3⅛	3¾	3¾	3¾	4⅜	4⅜	4⅜	4⅜	5	5	5	5	5⅝	5⅝	5⅝	6¼	7
Frames to Shell in After Peak; on Flat of Floor Forward in Deep Tanks; and for ·15 L at Fore End; Tank Stiffeners to Plating; Auxiliary Seating, etc.; Spacing	3½	3½	3½	3½	4⅛	4⅛	4⅛	4¾	4¾	4¾	4¾	5½	5½	5½	5½	6¼				
Shell Clips; Beams on Alternate Frames; Frames to Shell Where Spacing Exceeds 27 Inches; Spacing	3¾	3¾	3¾	3¾	4½	4½	4½	5¼	5¼	5¼	5¼	6	6	6	6	6¾				
Frames; Beams, Keelsons, Bulkhead, Stiffeners, and Girder Work Generally; Spacing	4½	4½	4½	4½	5¼	5¼	5¼	6¼	6¼	6¼	6¼	7	7	7	7	8				
Casing Stiffeners, etc.; Spacing	5	5	5	5	6	6	6	7	7	7	7	8								

Cut 78.

The size of rivets and the breadth of seams, end laps and butt straps are given in Cut 79.

BREADTHS OF SEAMS, END-LAPS AND BUTT STRAPS

BREADTHS AND SIZES ARE GIVEN IN INCHES

THICKNESS OF PLATE	·18–·34	·36–·48	·50–·68	·70–·88	·90–1·12	1·14–1·26	1·28–1·38
SIZE OF RIVET	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
Breadths of—							
Single-riveted Seams	2¼	2½	3	3½	4	......	......
Zig-zag-riveted Seams	3¼	3¾	4⅜	5	5⅝	6¼	......
Double-riveted Seams	3¾	4½	5¼	6	6¾	7½	8¼
Double-riveted End-laps	4⅜	5¼	6⅛	7	......	......	......
Treble-riveted End-laps	6¼	7½	8¾	10	11¼	12½	14
Quadruple-riveted End-laps	......	9¾	11⅜	13	14¾	16½	18
Quintuple-riveted End-laps	......	......	......	16½	18½	20½	23
Double-riveted Butt Straps	8	9¾	11⅜	13	......	......	......
Treble-riveted Butt Straps	......	14¼	16½	19	21½	......	......
Quadruple-riveted Butt Straps	......	18¾	22	25	28	31½	34½
Quintuple-riveted Butt Straps	......	......	......	31	35	39	43

Cut 79.

RIVETS

Pan headed rivets for use in watertight work and under the engines are to be swelled in the neck so as to fill the countersink due to the punching, and are to be of the following proportions:

Diameter at top of swelling = 1.12 times rivet diameter.
Diameter at base of head = 1.60 times rivet diameter.
Diameter at top of head = Rivet diameter.
Depth of head = .70 times rivet diameter.

In bulkheads, tunnel, rudder and other watertight work, points are to be hammered, not snapped.

Pan headed rivets are to be used for work under the engines and in the shell plating. Countersunk headed rivets are not to be used for watertight work nor in important parts of the structure, unless passed upon by the bureau.

In the case of heavy forgings and castings, where excessive length of rivets would prevent their being properly stayed up, sufficient tap riveting is to be adopted.

HOLES

Holes must be punched from the faying side.

Holes in three-ply and four-ply work are to be fair, unfair holes are to be reamed out after the work is screwed up, and they are to be countersunk then and the size of the rivet suitably increased.

Countersink is to extend through the plate when the thickness is under .60″.

Countersink is to extend through at least 90% of the thickness of a plate where the thickness is over .60″.

Holes in liners are not to be larger than those in the plates or bars. Lining pieces under outside strakes of plating are to be of steel in one length, and are to have a breadth not less than $3\frac{1}{2}$ times the diameter of the rivets.

Punches should be kept in good order, and the die or bolster used for steel work as small as possible, so as to avoid excessive "burr" around the hole.

ASSEMBLING WORK

All projections such as "burr" from punching, shearing, or drilling are to be removed from faying surfaces, and the work is to be thoroughly closed up with a sufficient number of service bolts before riveting is commenced. Unfair holes are to be reamed fair, not cut, and riveted work plied up close, so that an ordinary testing knife cannot be inserted between surfaces. Rivet points are to be full in the finish.

RIVETING IN GENERAL

Where adjoining plates differ in thickness the riveting of end connections is governed by the lesser thickness.

In seams it may also be governed by the smaller thickness.

In boundary angles it is governed by the lesser thickness, whether plate or bar.

The overlapping of angles, vis reverse angle or frame angle, floorplate on frame, etc., is not to be less than called for in the following table of sizes of angle flanges in terms of the size of rivet used.

SIZE OF ANGLE FLANGES

Size of Rivet.	Single Riveting.	Zigzag Riveting.	Chain Riveting.
⅝″	2½″	4″	4½″
¾″	3″	4½″	5″
⅞″	3½″	5″	6″
1″	3½″	6″	7″
1⅛″	4″	7″	8″
1¼″	4½″	8″	9″
1⅜″	5″	8″	9″

Bar Keels, Stems, and Stern Posts are to have rivets of sufficient diameter to insure sound workmanship. The following sizes limit the length or vice versa.

$\frac{3}{4}''$	rivets may be used when the total rivet length is under	$3''$
$\frac{7}{8}''$	" " " " " " " " "	$5''$
$1''$	" " " " " " " " "	$6''$
$1\frac{1}{8}''$	" " " " " " " " "	$8''$
$1\frac{1}{4}''$	" " " " " " " " "	$10''$

Where the length is too great to permit sound work, tap rivets are to be used.

Rudder Arms are to have rivets of no less size than required for the rudder plate, and are to be reeled at the inner end and spaced 6 diameters in each row, gradually closing up until the spacing at the outer end does not exceed 4 diameters in each row. The rivets are to have countersunk heads and hammered points.

Plate Keels are recommended as being fitted as outside strakes. End connection on plates under .60″ thickness may be double riveted; on plates .60″ to. 80″ treble riveted, and on .80″ plates quadruple riveted, the spacing of rivets in each row is to be $3\frac{1}{2}$ diameters in each case.

Center Girder Plates are to have overlapped end connections with the riveting required for midship plates, but the spacing of girder butts. The bottom angles are to have rivets 5 diameters apart, the top angles 7 diameters apart, except under the engines where the spacing is $5\frac{1}{2}$ diameters apart.

Keelsons are to have horizontal plates riveted as required for their thickness and for Girder butts, and the spacing in the top angles not to exceed 7 diameters, and in the reverse angle not to exceed 5 diameters.

Frames and Reverse Angles connected to plating are to have rivets spaced not more than 7 diameters, and where double riveting is required the spacing applies to each row. Rivet holes in frames, in way of shell seams, are to be drilled after the frames are faired in position. The rivet holes at the round of bilge are not to be punched until after the frames are turned.

Web Frames and Side Stringers. The riveting in butts of plates is as required as for Girder butts. Face bars are to be attached to the plates by rivets spaced not more than 7 diameters, frame bars to shell and web plates by rivets spaced not more than $5\frac{1}{2}$ diameters. When frame bars are double riveted the rivets are to be spaced not more than 8 diameters for zigzag riveting, and not more than 7 diameters with chain riveting, in each row.

Floors with single bottoms, which are not attached to center girders, are to have riveting required for midship plates, and spacing as for girder butts.

Beams. The spacing of rivets connecting plating to beams is not to exceed 7 diameters, and where beams are fitted to alternate frames the spacing is not to exceed 6 diameters.

In the riveting of beam knees not more than two holes are to be punched in each knee before the beam is faired in place.

Attachments. The rivets in beam knees, brackets, and overlaps on brackets are not to be spaced more than 5 diameters with single and chain riveting, nor more than 7 diameters in each row for zigzag riveting. The riveting of these various attachments is set forth in Cut 80.

ATTACHMENTS

SIZES ARE GIVEN IN INCHES

DEEP FRAMES, CHANNELS, WEB FRAMES

Depth	Brackets Rivets in each Arm		Clips Rivets in each Flange		Depth	Brackets Rivets in each Arm		Clips Rivets in each Flange	
	No.	Size	No.	Size		No.	Size	No.	Size
6	3	$\frac{3}{4}$	2	$\frac{3}{4}$	28	30	$\frac{7}{8}$	17	$\frac{7}{8}$
$6\frac{1}{2}$	4	$\frac{3}{4}$	3	$\frac{3}{4}$	29	32	$\frac{7}{8}$	18	$\frac{7}{8}$
7	5	$\frac{3}{4}$	3	$\frac{3}{4}$	30	20	Double Connections $\frac{7}{8}$	20	$\frac{7}{8}$
$7\frac{1}{2}$	6	$\frac{3}{4}$	4	$\frac{3}{4}$	31	21	$\frac{7}{8}$	12	Double Connections $\frac{7}{8}$
8	7	$\frac{3}{4}$	4	$\frac{3}{4}$	32	22	$\frac{7}{8}$	13	$\frac{7}{8}$
9	7	$\frac{7}{8}$	4	$\frac{7}{8}$	33	24	$\frac{7}{8}$	14	$\frac{7}{8}$
10	8	$\frac{7}{8}$	5	$\frac{7}{8}$	34	26	$\frac{7}{8}$	15	$\frac{7}{8}$
11	9	$\frac{7}{8}$	5	$\frac{7}{8}$	35	28	$\frac{7}{8}$	16	$\frac{7}{8}$
12	10	$\frac{7}{8}$	6	$\frac{7}{8}$	36	30	$\frac{7}{8}$	17	$\frac{7}{8}$
13	12	$\frac{7}{8}$	7	$\frac{7}{8}$	37	32	$\frac{7}{8}$	18	$\frac{7}{8}$
14	13	$\frac{7}{8}$	8	$\frac{7}{8}$	38	34	$\frac{7}{8}$	19	$\frac{7}{8}$
15	14	$\frac{7}{8}$	8	$\frac{7}{8}$	39	36	$\frac{7}{8}$	20	$\frac{7}{8}$
16	15	$\frac{7}{8}$	9	$\frac{7}{8}$	40	38	$\frac{7}{8}$	21	$\frac{7}{8}$
17	16	$\frac{7}{8}$	9	$\frac{7}{8}$	41	40	$\frac{7}{8}$	22	$\frac{7}{8}$
18	17	$\frac{7}{8}$	10	$\frac{7}{8}$	42	42	$\frac{7}{8}$	23	$\frac{7}{8}$
19	18	$\frac{7}{8}$	10	$\frac{7}{8}$	43	44	$\frac{7}{8}$	24	$\frac{7}{8}$
20	19	$\frac{7}{8}$	11	$\frac{7}{8}$	44	46	$\frac{7}{8}$	26	$\frac{7}{8}$
21	20	$\frac{7}{8}$	11	$\frac{7}{8}$	45	48	$\frac{7}{8}$	28	$\frac{7}{8}$
22	21	$\frac{7}{8}$	12	$\frac{7}{8}$	46	....	....	30	$\frac{7}{8}$
23	22	$\frac{7}{8}$	12	$\frac{7}{8}$	47	....	....	24	1
24	23	$\frac{7}{8}$	13	$\frac{7}{8}$	48	....	....	25	1
25	24	$\frac{7}{8}$	14	$\frac{7}{8}$	49	....	....	26	1
26	26	$\frac{7}{8}$	15	$\frac{7}{8}$	50	....	....	27	1
27	28	$\frac{7}{8}$	16	$\frac{7}{8}$	51	....	....	28	1

BULB ANGLES

Depth	Brackets Rivets in each Arm		Clips Rivets in each Flange	
	No.	Size	No.	Size
6	3	$\frac{5}{8}$	2	$\frac{5}{8}$
$6\frac{1}{2}$	3	$\frac{3}{4}$	2	$\frac{3}{4}$
7	4	$\frac{3}{4}$	3	$\frac{3}{4}$
$7\frac{1}{2}$	5	$\frac{3}{4}$	3	$\frac{3}{4}$
8	6	$\frac{3}{4}$	4	$\frac{3}{4}$
9	7	$\frac{3}{4}$	4	$\frac{3}{4}$
10	7	$\frac{7}{8}$	4	$\frac{7}{8}$
11	8	$\frac{7}{8}$	5	$\frac{7}{8}$
12	9	$\frac{7}{8}$	6	$\frac{7}{8}$

Cut 80.

Stanchions and Deck Girders. The rivets in plate seams of built pillars are to be spaced 6 diameters, and those in bars not more than 8 diameters. The rivets connecting face angles to girder plates are to be spaced not more than 7 diameters. The rivets in deck clips are to be spaced not more than 6 diameters. Stanchions are to have the following riveting:

Stanchions under $3\frac{1}{2}''$ diameter to have 2 $\frac{7}{8}''$ rivets in each palm.
Stanchions of $3\frac{1}{2}''$ to $4\frac{1}{2}''$ diameter 2 1″ rivets in each palm.
Stanchions of $4\frac{1}{2}''$ to $5\frac{3}{4}''$ diameter 3 1″ rivets in each palm.
Stanchions of $5\frac{3}{4}''$ and over diameter 4 1″ rivets in each palm.

Bulkheads. The rivets in bulkhead frames are to be spaced 5 diameters in the shell flange, and as required for watertight seams in the bulkhead flange.

Bulkhead stiffeners to plating spacing is 7 diameters.

Deep tank stiffeners spacing is $5\frac{1}{2}$ diameters.

Bulkheads of deep tanks to be double riveted.

The following table gives requirements for the riveting of end attachments in bulkhead construction, Cut 81.

BULKHEADS

SIZES ARE GIVEN IN INCHES

ATTACHMENTS FOR STIFFENERS IN PASSENGER VESSELS

Type of Stiffener and depth in Inches	BRACKETS				CLIPS	
	Thickness	Flange Width	Rivets in each Arm		Rivets in each Flange	
			No.	Size	No.	Size
Angles, 3 to 6	·34	......	3	$\frac{3}{4}$	2	$\frac{3}{4}$
Bulb angles, 5 to 6	·36	......	3	$\frac{3}{4}$	2	$\frac{3}{4}$
" $6\frac{1}{2}$	·40	......	4	$\frac{3}{4}$	3	$\frac{3}{4}$
" 7 and $7\frac{1}{2}$	·44	......	5	$\frac{3}{4}$	3	$\frac{3}{4}$
" 8 and $8\frac{1}{2}$	·44	$2\frac{1}{2}$	6	$\frac{3}{4}$	4	$\frac{3}{4}$
" 9 and $9\frac{1}{2}$	·44	$2\frac{3}{4}$	7	$\frac{3}{4}$	4	$\frac{3}{4}$
" 10 and $10\frac{1}{2}$	·44	3	7	$\frac{7}{8}$	4	$\frac{7}{8}$
" 11 and $11\frac{1}{2}$	·44	$3\frac{1}{4}$	8	$\frac{7}{8}$	5	$\frac{7}{8}$
" 12	·44	$3\frac{1}{2}$	9	$\frac{7}{8}$	6	$\frac{7}{8}$
Channels, $12\times3\frac{1}{2}$	·44	$3\frac{1}{2}$	10	$\frac{7}{8}$	6	$\frac{7}{8}$
" 12×4	·46	$3\frac{1}{2}$	11	$\frac{7}{8}$	8	$\frac{7}{8}$
" 13×4	·48	4	12	$\frac{7}{8}$	8	$\frac{7}{8}$
" 14×4	·48	4	13	$\frac{7}{8}$	8	$\frac{7}{8}$
" 15×4	·50	$4\frac{1}{2}$	14	$\frac{7}{8}$	8	$\frac{7}{8}$
" 16×4	·52	$4\frac{1}{2}$	15	$\frac{7}{8}$	9	$\frac{7}{8}$
" 17×4	·54	$4\frac{1}{2}$	16	$\frac{7}{8}$	9	$\frac{7}{8}$

Cut 81.

Panting Arrangement. In the after peak and for 15% of the forward length of the ship from keel to well above the load line, the spacing of rivets connecting shell plating to frames and stringers is not to exceed $5\frac{1}{2}$ diameters. Shell clips in peaks are not to have rivets spaced more than 5 diameters.

Shell Plating. Seams in shell plating in vessels under 250 feet long may be single riveted.

Seams at ends in ships under 300 feet long may be single riveted.

Seams in superstructure may be single riveted, except at breaks.

Seams in superstructure at breaks to be riveted as tabulated.

Seams in vessels having machinery in after end to be double riveted on the flat of floor forward of midship half length.

All other shell plating is to have double riveted seams.

Gunwale Angles having flanges of widths for single and double riveting are to have rivet spacing as required for watertight seams.

Machinery Casings which are exposed to the weather are to be riveted in accordance with requirements for watertight bulkheads. Machinery casings not so exposed, and hence not required to be watertight may have 6 diameter spacing in seams and end connections, except in the butts of casings and other parts essential to girder efficiency.

Masts and Spars. Masts and bowsprits in sailing vessels may have single riveted seams where angle stiffeners are fitted throughout their length. They shall be double riveted where no stiffeners are fitted.

Masts in steamers, topmasts and yards of sailing vessels may have single riveted seams.

End connections in masts from below the wedging up to the cap are to be treble riveted. Top masts for sailing vessels are to be treble riveted.

Doubling Plates are to be single riveted at edges with rivets spaced not more than 5 diameters. The rivets in the body of the plate are to be sufficiently close to bring the plate surfaces well home, and should be put in before the edge rivets.

Gusset connections for bracket floors are given in Cut 82.

GUSSET CONNECTIONS ON BRACKET FLOORS

Length of Vessel in Feet	Depth of Vessel in Feet	Amidships and After Body		Forward of Midship Half Length	
		Spacing	Riveting	Spacing	Riveting
200 and under 250	16 and under 20	5 frames apart	Four ¾-Rivets	4 frames apart	Four ¾-Rivets
250 and under 300	20 and under 24	4 frames apart	Five ¾-Rivets	3 frames apart	Five ¾-Rivets
300 and under 350	24 and under 27	3 frames apart	Five ⅞-Rivets	2 frames apart	Five ⅞-Rivets
350 and under 400	27 and under 30	3 frames apart	Eight ⅞-Rivets	2 frames apart	Eight ⅞-Rivets
400 and under 450	30 and under 33	2 frames apart	Eight ⅞-Rivets	1 frame apart	Five ⅞-Rivets
450 and under 500	33 and under 36	1 frame apart	Five ⅞-Rivets	Continuous plate	Seven ⅞-Rivets
500 and under 550	36 and under 39	1 frame apart	Six ⅞-Rivets	Continuous plate	Eight ⅞-Rivets
550 and under 600	39 and under 42	Continuous plate	Seven ⅞-Rivets	Continuous plate	Ten ⅞-Rivets
600 and under 650	42 and under 45	Continuous plate	Eight ⅞-Rivets	Continuous plate	Ten ⅞-Rivets
650 and under 700	45 and under 48	Continuous plate	Eight 1-Rivets	Continuous plate	Ten 1-Rivets

Cut 82.

LLOYD'S REGISTER OF SHIPPING

Rules for Rivets and Riveting

TEST REQUIREMENTS

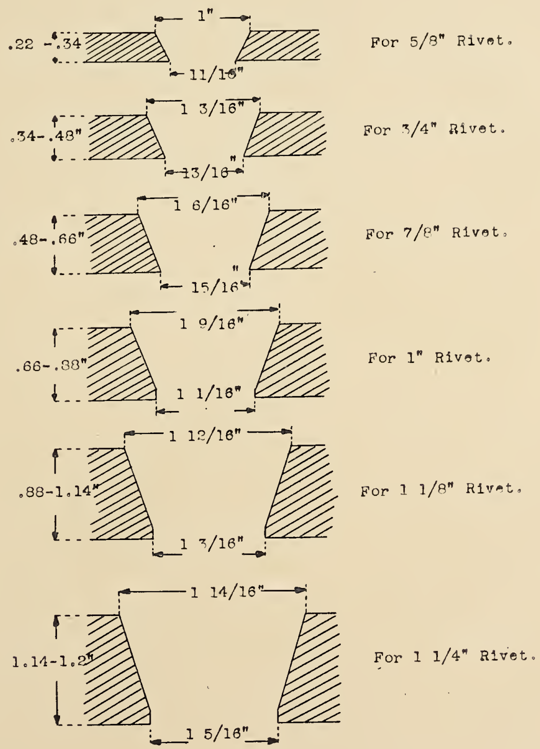
Rivet Bars

Tensile strength	25 to 30 tons per square inch.
Elongation (In 8 times diameter)	25%
Elongation (In 4 times diameter)	30%

Manufactured Rivets

Shank Bend (Cold)	180° Flat on itself without fracture.
Flattening Test (Hot)	Head to flatten to $2\frac{1}{2}$ times the diameter of the shank without tearing.

In Cut 83, the size of rivet to be used with various sizes of plate is given as required by Lloyd's. The proportioning of countersinking for various thickness of plate and size of rivet is also illustrated.

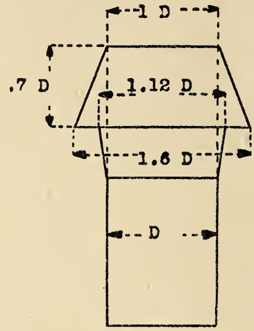


Cut 83.

LLOYD'S REGISTER REQUIREMENTS

Standard Rivet

Form to be used in Outside Plating.



Cut 84.

The tapered neck of rivets to be of suitable length in relation to the thickness of the plate in which it is intended to be used.

The following table gives Rules for Riveting as required by Lloyd's.

RIVETING

Thickness of Plate.	.22″ to .34″	.34″ to .48″	.48″ to .66″	.66″ to .88″	.88″ to 1.14″	1.14″ to 1.20″
Diam. of Rivet.	⅝″	¾″	⅞″	1″	1⅛″	1¼″
Spacing of Frames.	Number of Rivets in Each Row.					
20″	7	3	..	..	..	..
20½″	7	6	..	..	..	..
21″	7	6	5	..	..	..
21½	..	6	5	..	..	..
22″	..	6	5	..	..	..
22½″	..	6	5	..	..	..
23″	..	6	5	5	..	..
23½″	..	7	6	5	..	..
24″	..	7	6	5	..	..
24½″	..	..	6	5	..	..
25″	..	..	6	5	..	..
25½″	..	..	7	6	..	..
26″	..	..	7	6	5	..
26½″	..	..	7	6	5	..
27″	..	..	7	6	5	..
27½″	..	..	7	6	6	..
28″	..	..	7	6	6	5
28½″	..	..	8	7	6	5
29″	..	..	8	7	6	5
29½″	..	..	8	7	6	5
30″	..	..	8	7	6	5
30½″	..	..	..	7	6	6
31″	..	..	..	7	6	6
31½″	..	..	..	8	7	6
32″	..	..	..	8	7	6
32½″	..	..	..	8	7	6
33″	..	..	..	8	7	6

In the construction of ships intended to carry oil in bulk, special care must be taken to provide against local stresses at the end of oil spaces, super-structures, etc., and for the necessary compensation for the close spacing of the rivets throughout the structure. Solid sections should be used as much as possible, flanged ends of plates being preferred to angle connections.

The spacing of rivets connecting different members of the structure in oil spaces is not to exceed $5\frac{1}{2}$ diameters. Two rivets are to be fitted through all bars in way of double riveted seams. Three-ply work, close bevels and the use of packing are to be avoided to the utmost extent, and any rivet holes which are the least unfair are to be reamed and larger rivets fitted.

The foregoing covers riveting in ship construction quite completely, but many persons engaged in ship construction may have suggestions to offer in relation to tables, etc. While this compilation is gotten up with the idea of helping them in their work, there are probably many tables that are very handy to the ship layer out or designer, and any suggestions in relation to this subject would be welcomed by us.

To conclude this section it might be stated that the United States Shipping Board estimates that the normal tonnage of merchant marine will not be restored to the state it was in prior to the World War for many years. Requirements for tonnage have normally increased, so that intensive ship construction may be considered as a basic industry for this generation.

As far as the United States Merchant Marine is concerned, it might be said that while the present Shipping Laws restrain, they do not prevent the operation of American vessels.

SECTION VIII

BRIDGES

The proportioning given in Structural work will largely follow for Bridge construction, although there are some standards adopted in this work, peculiar to itself. Generally in Bridge design the allowable stresses are reduced, as compared to Structural work.

The composition of steel used for structural steel for bridges has been standardized by the American Society for testing materials, and which are as follows: The steel is to be made by the Open Hearth Process.

	Structural Steel for Bridges.	Rivet Steel.
Phosphorous, Acid, not over	0.060	0.040
Phosphorous, Basic, not over	0.040	0.040
Sulphur, not over	0.050	0.045
Physical Requirements:		
Tensile strength, lbs. sq. in.	55000—65000	46000—56000
Yield Point, Min., lbs. sq. in.	½ TS	½ TS
Elongation in 8″, Min. %	1500000÷TS	1500000÷TS
Elongation in 2″	22%	......
Cold bend	A.	180° Flat.
Number Tests, per melt:		
Tension	1	1
Bend	1	1

A. Material $\frac{3}{4}''$ or under in thickness flat on itself.
Over $\frac{3}{4}''$ and to $1\frac{1}{4}''$ in thickness around a pin whose diameter is equal to the thickness of the material specimen.
Over $1\frac{1}{4}''$ in thickness around a pin the diameter of which is twice the thickness of the specimen.

Eyebars test are required to bend without failure as follows:

$\frac{3}{4}''$ or under around a pin $d = t$.
$\frac{3}{4}''$ to $1\frac{1}{4}''$ around a pin $d = 2\,t$.
Over $1\frac{1}{4}''$ around a pin $d = 3\,t$.

Many large and important bridges have been constructed in the last few years, notably the Manhattan Bridge, Blackwells Island Bridge, the Hell Gate Bridge, and the Quebec Bridge, the latter of which had two disastrous failures during its construction.

Due to the curtailment of all railroad improvements, there has been a serious lack of new Railroad Bridge building. Many Railroad Bridges were never designed to carry the traffic imposed upon them, and the number of such structures that have been doctored up to strength, by patching up, is almost beyond belief.

In the construction of the Hell Gate Bridge, 8x8 angles were used, these being the largest size obtainable. Better proportioning would have resulted if 10x10, or 12x12 angles could have been obtained. It is the present tendency to utilize as large sections as possible, and the Steel Manufacturers will have to consider the advisability of rolling the heavier sections to meet this requirement.

Special steels have been tried, notably in the Blackswell Island Bridge where Nickel steel was extensively used. Silicon steel is in use in the Ohio River Bridge at Metropolis, Illinois, this steel containing approximately 0.35 Silicon. Tests of this steel give higher yield point and tensile strength without reducing the elongation or reduction of area. The Silicon steel is used for top chords, main posts, main diagonals, and for the end panels of bottom chords. All other rolled material in the bridge is of medium carbon steel.

In the Manhattan Bridge Nickel Steel rivets were used the specifications for which were:

Nickel Steel Rivets.

Tensile strength......	70000 to 80000
Yield point..........	45000
Elongation in 8″......	1600000÷TS.

In the Manhattan Bridge Mediun Carbon Steel rivets were also used, the requirements for which were:

Medium Carbon Steel Rivets.

Tensile strength......	50000 to 58000
Yield point..........	30000
Elongation in 8″......	1600000÷TS.
Reduction area.......	50%

In bridge design the following points should be given consideration as far as riveting is concerned.

Shearing and Bearing of Rivets

The rivets connecting parts of any member must be so spaced that the shearing stress shall not exceed 9000 pounds per square inch, or $\frac{3}{4}$ of the usual allowed strain on that member.

The pressure upon the bearing surface per square inch of the projected semi intrados (diameter times the thickness of the piece) of the rivet hole shall not exceed 15000 pounds, or $1\frac{1}{2}$ times the allowed strain on that member.

For field riveting the above values should be reduced to 2/3 the value given.

Rivets must not be used in direct tension on any part of a bridge structure.

Generally the pitch in all classes of work should never exceed 6 inches, or 16 times the thinnest outside plate.

The pitch of the rivets should never be less than 3 diameters of the rivet. The pitch of rivets at the ends of compression members should not exceed 4 diameters of the rivet for a length equal to 2 times the width of the member.

The rivets generally used in bridge construction are $\frac{5}{8}''$, $\frac{3}{4}''$, and $\frac{7}{8}''$ in diameter, and are Button head.

The distance between the edge of any piece and the center of a rivet hole must never be less than $1\frac{1}{4}''$, except for bars less than $2\frac{1}{2}''$ wide. When practical it shall be at least 2 diameters of the rivet.

On account of the nature of the work, as much of the bridge work should be done in the shop as possible, thereby driving the maximum number of rivets by pressure machines. In any case no rivets exceeding $\frac{7}{8}''$ in diameter should be hand driven, and they should not be allowed.

Field riveting must be reduced to the minimum, and if possible should be entirely avoided in Bridge construction.

CHAPTER X

RAILWAY CAR AND LOCOMOTIVE CONSTRUCTION

There are about 2,500,000 freight cars in service in this country, and while this number includes the old wooden freight cars, the construction of replacements is largely of steel construction. It was formerly figured that the life of a steel freight car was 25 years, but more recent data seems to indicate that this is much too high a figure. Construction of railroad freight cars is done at the rate of approximately 50,000 cars per year, although the capacity of the country is probably four times this amount.

Locomotives are manufactured for United States railroad use at about the rate of 5000 per year, and about that same number are made for foreign account. Probably if urgently pushed this country would have a capacity of some 15,000 standard locomotives per year. Locomotive building has been standardized, types adhered to, methods of construction comparable to the best productive methods, and a locomotive can be turned out much more rapidly than was practiced a few years ago.

The construction of locomotives and the fabrication of steel cars must comply with the requirements for high grade structural work, and of the Boiler Code. In addition the requirements of the Master Car Builders Association, now known as the American Railroad Association, and of the Interstate Commerce Commission must be met.

Following are the grades of steel used in this type of construction as standardized by the American Society for Testing Materials:

Material.	Structural for Locomotives.	Structural for Cars.	Plates for Cold Pressing.
Open Hearth Steel:			
Phosphorous, Acid, under	.050	.060	.060
Phosphorous, Basic, under	.050	.040	.040
Sulphur, under	.050	.050	.050
Tensile strength	55000—65000	50000—65000	48000—58000
Yield Point	½ TS	½ TS	½ TS
Elongation in 8″, Min. %	1500000÷TS	1500000÷TS	1500000÷TS
Bends	A.	A.	A.

Note A. Bend Tests:—The test specimen shall bend cold through 180° without cracking on the outside of the bent portion as follows:

For material ¾″ or under in thickness flat on itself.

For material over ¾″ and up to and including 1¼″ in thickness around a pin the diameter of which is equal to the thickness of the specimen.

For material over 1¼″ in thickness around a pin equal to twice the thickness of the specimen.

Modifications in Elongation:—For material over $\frac{3}{4}''$ in thickness a deduction of 1 from the elongation specified shall be made for each increase of $\frac{1}{8}''$ in thickness above $\frac{3}{4}''$ to a minimum of 18%.

For material under 5/16″ in thickness, a deduction of 2.5 from the percentage of elongation in 8″, as specified shall be made for each decrease of 1/16″ in thickness below 5/16″.

REQUIREMENTS FOR RIVET ROUNDS

The requirements of the American Railroad Association and of the American Society for Testing Materials are compared below:

Requirements of =	A.S.T.M.	A.R.A.	A.R.A.
For Rivet Steel for =	Car Rivets.	Locomotive Rivets.	Passenger & Freight Car Rivet Steel.
Open Hearth Steel:			
Carbon	......	......	Optional.
Manganese	......	.30 to .50	Optional.
Phosphorous, Acid	.040	.040	.040
Phosphorous, Basic	.040	.040	.040
Sulphur	.045	.045	.050
Physical requirements:			
Tensile strength	45000—60000	45000—55000	45000—60000
Yield point	½ TS	½ TS	......
Elongation in 8″	1500000÷TS.	1500000÷TS (+)	1500000÷TS (+)
Bend Test	180° flat	180° flat (*)	180° flat

(*). Quench Bend required also, 180° flat.
(+). Elongation need not exceed 30%.

The principal parts of a Steel car of any type are the framing, trucks, breaks, and draft gear.

The framing consists of center, side and end sills, with suitable bracing. The floor, sides, and end plates are riveted to the framing and securely braced.

The car must meet the requirements of the American Railroad Association in regards couplers, trucks, wheels, axles, etc.

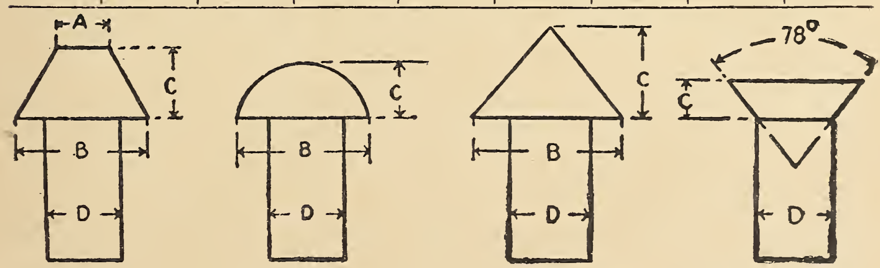
The car must meet the rules of the Interstate Commerce Commission in relation to hand brakes, brake steps, sill steps, side handholds, end handholds, uncoupling levers, etc., for number, dimensions and location.

DIMENSIONS OF RIVET HEADS

Rivet heads for car construction shall conform to the dimensions shown on the purchaser's standard drawings when so specified, otherwise the head shall conform, within 5% above or below, to the dimensions shown in the following table.

DIMENSIONS FOR RIVETS.

Diam. of Rivet.	Cone Head.			Button Head.		Steeple Head.		Countersunk Head.
D	A	B	C	B	C	B	C	C
1/4	15/64	7/16	7/32	7/16	3/16	1/2	1/4	1/8
5/16	19/64	35/64	9/32	35/64	15/64	5/8	5/16	5/32
3/8	23/64	21/32	21/64	21/32	9/32	3/4	3/8	3/16
7/16	27/64	49/64	25/64	49/64	21/64	7/8	7/16	7/32
1/2	15/32	7/8	7/16	7/8	3/8	1	1/2	1/4
9/16	17/32	63/64	1/2	63/64	27/64	1 1/8	9/16	9/32
5/8	19/32	1 3/32	35/64	1 3/32	15/32	1 1/4	5/8	5/16
11/16	41/64	1 13/64	39/64	1 13/64	33/64	1 3/8	11/16	11/32
3/4	45/64	1 5/16	21/32	1 5/16	9/16	1 1/2	3/4	3/8
13/16	49/64	1 27/64	23/32	1 27/64	39/64	1 5/8	13/16	13/32
7/8	53/64	1 17/32	49/64	1 17/32	21/32	1 3/4	7/8	7/16
15/16	7/8	1 41/64	53/64	1 41/64	45/64	1 7/8	15/16	15/32
1	15/16	1 3/4	7/8	1 3/4	3/4	2	1	1/2
1 1/16	1	1 55/64	15/16	1 55/64	51/64	2 1/8	1 1/16	17/32
1 1/8	1 1/16	1 31/32	63/64	1 31/32	27/32	2 1/4	1 1/8	9/16
1 3/16	1 1/8	2 5/64	1 3/64	2 5/64	57/64	2 3/8	1 3/16	19/32
1 1/4	1 11/64	2 3/16	1 3/32	2 3/16	15/16	2 1/2	1 1/4	5/8
1 3/8	1 9/32	2 13/32	1 13/64	2 13/32	1 1/32	2 3/4	1 3/8	11/16
1 1/2	1 13/32	2 5/8	1 5/16	2 5/8	1 1/8	3	1 1/2	3/4
1 3/4	1 41/64	3 1/16	1 17/32	3 1/16	1 5/16	3 1/2	1 3/4	7/8
2	1 7/8	3 1/2	1 3/4	3 1/2	1 1/2	4	2	1



Cone Head.
$A = \frac{15}{16} \times D$
$B = 1\frac{3}{4} \times D$
$C = \frac{7}{8} \times D$

Button Head.
$B = 1\frac{3}{4} \times D$
$C = \frac{3}{4} \times D$

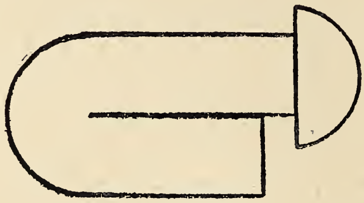
Steeple Head.
$B = 2 \times D$
$C = D$

Countersunk Head.
$C = \frac{1}{2} \times D$
Taper=78 degrees

Following are the Master Car Builders, or American Railroad Association requirements for rivets.

Rivets for Passenger and Freight Equipment Cars

Bend Test:—The Rivet shank shall bend cold through 180° flat on itself as shown in Cut 86, without cracking on the outside of the bent portion.



Cut 86.

Flattening Test:—Rivet heads shall be flattened sideways, when cold, to a thickness of 1/3, and when at a driving heat to a thickness of 1/4 the original diameter of the shank, without splitting.

Number of Tests:—One bend and one flattening test shall be made from each lot of 100 kegs of each diameter or from each diameter in any one melt, each of which must conform to the requirements specified.

If any test specimen from the rivets originally selected contains surface defects not visable before testing, but visable after testing, one retest shall be allowed.

Samples representing a lot of rivets shall be marked in a manner that will not impair their value for test purposes.

RIVETS FOR TANK AND UNDERFRAME

The requirements are substantially the same as for rivets given above.

It has been usual, however, to require 10 rivets from every 100 kegs of rivets for check analysis in case of dispute, regarding chemical composition.

RIVETS FOR LOCOMOTIVES

The rivets for locomotives use are used for Locomotive boilers.

Tension Tests:—Rivets shall conform to the requirements as listed, and the elongation measured in a gage length not less than four times the diameter of the rivet.

Cold Bend:—180° flat on itself without cracking.

Quench Bend:—The Rivet shank when heated to a light cherry red as seen in the dark, and not less than 1200° Farenheit, and quenched at once in water of a temperature between 80° and 90° Farenheit, shall bend 180° flat on itself without cracking on the outside bent portion.

Flattening Test:—Rivet heads shall flatten sidewise, when cold, to a thickness of 1/3, and when at a driving heat to a thickness of 1/4 of the original diameter of the shank, without splitting.

Number of Tests:—One Tension Test (when specified).
One Cold Bend.
One Quench Bend.
One Flattening Test.

From each lot of 50 kegs of each diameter or from each diameter in any one melt, each of which shall conform to the requirements specified.

Tension, bend, and flattening test specimens shall be of the full section of the rivets as manufactured.

When accurate accounts of the material have been kept and the melts can be identified, only one set of tests for each diameter in each melt shall be taken for the finished rivets.

If rivet bars or rivets have been cold worked, the test specimens shall be heated to a drawing heat and allowed to cool in air before testing.

Rivets for cars are largely $\frac{5}{8}''$ in diameter. In underframes of gondolas $\frac{3}{4}''$ and $1''$ rivets are largely used. In the construction of Oil Tank cars, the requirements for oil tightness are substantially the same as given for oil tight seams in Ship construction. It would be well for the Oil Tank Car Builders to note the composition of oil stops used in ship building as given in Chapter VII.

All punching and drilling in car construction must be done accurately, and the drifting of holes not permitted. Reaming should be done after the parts forming a built up member are secured by bolts. Buckles and lumps should be faired out before riveting is commenced, and cold hammering to make fits should not be permitted. Rivets should be driven by pressure tools or pneumatic hammers. Finished rivets should be first class, and loose and burned rivets cut out and replaced. No recupping of rivets after driving should be permitted.

CHAPTER XI

TANK, CHIMNEY, RIVETED PIPE, AND MISCELLANEOUS CONSTRUCTION

Large quantities of Riveted Steel Tanks, Smokestacks, Pipe, and other fabricated plate work are used industrially in this country. Much of this material is not made to standard specifications, although manufacturers of this type of apparatus have standardized their own products for the production benefits derived therefrom.

TANK STEEL

Tensile strength 55000 to 65000 pounds per square inch.

Shearing strength 45000 to 50000 pounds per square inch.

Tank plates made of soft steel, while the heads are made of flanging quality steel.

The operations conducted in the manufacture of tanks, smokestacks, etc., are as follows:

1. Laying Out: The plates, head disks, and shapes are layed out to template, and all holes located in the flat.

2. Punching: All material is carefully center punched, and clean, sharp center punches used. Clean and sharp punches and dies are necessary, and a clearance of approximately 1/32″ between punch and die is good practice.

3. Shearing: All calking edges must be bevel sheared or bevel planed to an angle of 70°.

4. Rolling and Bending to Shape: This work is done cold, thus avoiding strains due to heating, and should be done by pressure machinery.

5. Flanging: The use of a Flanging machine is to be preferred to the work done on a Stake table and hand work.

6. Riveting: This work is preferably done in a Hydraulic or Pneumatic Riveting machine, with mechanical Holder On. The proper pressure should be applied to different sizes of rivets and rivets allowed to properly "set," before pressure is removed.

7. Calking. Pneumatic Calking machines should be used, and equipped with a well rounded nose tool.

8. Testing: All fabricated work of this nature should be tested by water pressure if in tank or pipe form, a pressure $1\frac{1}{2}$ times the working pressure being used. Rivets should be tapped for condition in stack and other cylindrical work without bottoms, and all loose and burnt rivets cut out and replaced.

9. PAINTING: A good paint should be used for the preservation of all work, and to give neatness in appearance. It should be remembered that a single coat of paint furnished the maximum protection, as compared to any other coats subsequently applied, and this coat given by a manufacturer should be done with care and thoroughly.

10. GENERAL: No artificial methods of making tight joints should be permitted under any circumstances. Sal Amoniac used to rust tight a joint is dangerous, as in the majority of cases the Tank Builder does not know the use to which his tank will be put. Fillers if used should be limited to the minimum.

The strength of riveted joints in this work would be as discussed previously, but in round numbers the efficiencies may be repeated as:

Single	Riveted Lap Joint	=	60%
Double	Riveted Lap Joint	=	70%
Triple	Riveted Lap Joint	=	75%
Triple	Riveted Butt Joint	=	84% (Double Straps).

Double riveting of seams in the round seams of pressure or storage tanks is unnecessary, and this is likewise true for rectangular tanks in general. There might be sizes of tanks that would require double riveting, but for general use the statement stands.

ROUND TANKS

TANK PLATES—$\frac{1}{4}''$ thick, of quality known as Tank steel.

COVER—No. 10 gage steel, of quality known as Blue Annealed.

BOTTON—For tanks under 12 feet in diameter, joined to shell by flanging. If over 12 feet, use $3 \times 3 \times 5/16''$ angle for corner connection.

COAMING—Upper edge of tank to have a $3 \times 3 \times 6/16''$ angle placed optionally inside or outside, as reinforcement.

SEAMS—Below water line single riveted with $\frac{5}{8}''$ rivets, spaced $2\frac{1}{4}''$ pitch. Rivets in Coaming angle spaced $8''$ pitch.

Round tanks for buildings are seldom large enough to require over $\frac{1}{4}''$ plate if strength only is considered. Greater thickness is sometimes used for durability. Round tanks are more economical the nearer the diameter and depth approach each other.

The thickness of a tank is found by using the following formula:

$$\text{Thickness} = \frac{D \times P}{TS \times FS \times E.}$$

Where:— D. = Diameter of Tank in inches.
P. = Pressure in pounds per square inch.
TS. = Tensile Strength of the Plate.
FS. = Factor of Safety. Usually taken as 4.
E. = Efficiency of the Riveted Joint, as given above.

ROUND PRESSURE TANKS

Straight seams should be double riveted, lap joints, or triple riveted butt joints as the strength required may indicate.

Round seams should be single riveted.

Dished heads should be proportioned as follows:

Diameter of Tank.	Thickness of Head.
36″ and under.	1/16″ thicker than shell.
36″ to 96″	1/8″ thicker than shell.
96″ and over.	1/4″ thicker than shell.

For reversed heads, as used on bottoms, the values should be:

Diameter of Tank.	Thickness of Head.
72″ and under.	$\frac{1}{8}$″ thicker than normal head.
72″ to 96″	$\frac{1}{4}$″ thicker than normal head.

Do not reverse heads in diameters over 96″.

RECTANGULAR TANKS

Rectangular tanks are the more economical the more nearly they approach being a Cube, but on account of utility and strength they should be kept as shallow as possible.

Following are proportions of these tanks:

Height.	Thickness of Plate.	Rivets.	Spacing.
Under 6 feet..........	¼″	⅝″	2¼″
6 feet to 8 teet........	$\frac{5}{16}$″	⅝″	2¼″
Over 8 feet...........	⅜″	¾″	2½″

A rectangular tank must be braced, the maximum strain being on the bottom, hence braces should be nearer together towards the bottom. Braces are spaced approximately 4 feet apart horizontally and as follows in the vertical:

Depth of Tank.	Bracing.
5 feet.	At top only.
6 feet.	One 3 feet from bottom, one at top.
7 feet.	One at 2 feet from bottom, one $4\frac{1}{2}$ feet from bottom, and one at top.
8 feet.	One 2 feet from bottom, one 5 feet from bottom, and one at top.

STACKS

Large numbers of Steel stacks are used in the construction of the modern office buildings, hotels, etc., and still larger quantities are used industrially. Guyed stacks are largely used industrially, while exterior and interior steel stacks supported by the building walls are used in buildings. In larger industrial plants self supporting stacks are used.

Stacks should be built in courses of steel plate not over 60 inches high, and so formed that each course telescopes into the bottom of the next succeeding course. It has been practice to make stacks heavier near the bottom than at the top, when as a matter of fact the stack should be built of the same weight material throughout, as the top is exposed to the action of condensation products and is more rapidly corroded than the bottom. Specifications generally read, half $\frac{1}{4}''$, and half 3/16″, or one-third $\frac{3}{8}''$, 5/16″ and $\frac{1}{4}''$. It would be better to make stacks of $\frac{1}{4}''$ or $\frac{3}{8}''$ throughout rather than thus specified.

Rivets should be of the following sizes:

Rivet.	Stack Plate.	Spacing.
$\frac{3}{8}''$	No. 10 Gage.	$3\frac{1}{2}$ inches.
$\frac{1}{2}''$	3/16″	"
$\frac{5}{8}''$	1/4″	"
$\frac{5}{8}''$	5/16″	"
$\frac{3}{4}''$	3/8″	"

Cone or Steeple heads are employed in this work, which standards have been given previously. Points should be the same as the head of the rivets used.

All seams should be single riveted, and flat driven inside field rivets permitted.

Stacks fastened to the outside of buildings sometimes give trouble due, to the condensation that takes place at the top, as mentioned above trickling through between the plates, and often spattering onto the building walls causing unsightly stains. To overcome this the rivets should be spaced closer and the seams calked.

Many office building stacks are carried in the interior of the building, and occasionally oval or rectangular stacks are used. Rectangular stacks are not usually fitted with angle connections at the corners, but are rounded there, to a radius of approximately 3″, and each course being of two plates, and thus having two vertical seams. New York Building Laws require that stacks be built of at least $\frac{1}{4}''$ plate, if lower than that thickness they must be galvanized.

Such stacks as mentioned above are supported by braces every floor, and if this is not entirely satisfactory the stacks should extend through to the boiler room floor, the stack terminating in an angle ring approximately $\frac{1}{8}''$ thicker than the material in the stack. Smoke Box Breaching should be inserted at the proper height.

Self supporting stacks should preferably not be over 25 times their diameter in height, as over this ratio strains become excessive. The bases should flare out to $1\frac{1}{2}$ times the diameter, and tapering to meet the normal diameter of the stack at approximately 1/16 of the height of the stack.

The thickness of the plate at the bottom need not exceed $\frac{1}{2}''$ as far as strength is concerned, while generally no part should be less than $\frac{1}{4}''$ thick. For durability 5/16″ plate should be used as the thinnest material.

Such stacks are usually lined, and provision should be made for supporting the brick work lining on the interior angle rings that can also be used as fasteners and stiffeners for the courses, which are assembled in from 20 to 25 foot lengths. The brickwork should not be in contact with the steel plate of the stack, but a space left which is filled with loam. Any openings out in the sides of stacks of this type should be carefully reinforced, as in the lower part of such stacks severe strains exist. Three-quarter rivets are generally used in the lower portion of such stacks and double chain riveting on zigzag riveting on the ends of the flare. The upper portion of such stacks may have $\frac{5}{8}''$ rivets spaced from 3 to $3\frac{1}{2}$ inches.

For convenience in the figuring of tanks the two following tables are given. One to determine the bursting pressure of cylindrical tanks, and the other for the number of gallons contained in various sizes.

THEORETICAL BURSTING PRESSURE—CYLINDRICAL SHELLS

JOINT EFFICIENCY—100 PER CENT
TENSILE STRENGTH OF STEEL—55,000 POUNDS PER SQUARE INCH

Inside Diameter	THICKNESS																				
	1/4	9/32	5/16	11/32	3/8	13/32	7/16	15/32	1/2	17/32	9/16	19/32	5/8	21/32	11/16	23/32	3/4	25/32	13/16	27/32	7/8
24	1146	1289	1432	1575	1718	1861	2005	2148	2292	......	......	......	......	......	......	......	......	......	......	......	......
26	1058	1190	1322	1452	1587	1718	1850	1984	2117	......	......	......	......	......	......	......	......	......	......	......	......
28	982	1104	1228	1350	1473	1596	1718	1841	1965	2086	2209	......	......	......	......	......	......	......	......	......	......
30	916	1030	1146	1260	1375	1489	1602	1718	1833	1947	2061	......	......	......	......	......	......	......	......	......	......
32	859	967	1074	1181	1289	1397	1502	1611	1719	1827	1934	2041	2148	......	......	......	......	......	......	......	......
34	809	910	1011	1111	1213	1314	1415	1517	1618	1718	1820	1921	2022	......	......	......	......	......	......	......	......
36	764	859	955	1050	1146	1241	1336	1432	1528	1623	1718	1814	1910	2004	2100	......	......	......	......	......	......
38	723	814	904	995	1085	1176	1266	1358	1446	1539	1629	1718	1808	1900	1990	......	......	......	......	......	......
40	687	773	859	945	1031	1117	1203	1290	1374	1460	1547	1633	1718	1805	1890	1975	2062	......	......	......	......
42	654	736	818	900	982	1067	1146	1228	1308	1391	1472	1556	1636	1718	1800	1882	1964	......	......	......	......
44	625	703	781	859	937	1015	1094	1171	1250	1328	1406	1485	1562	1640	1718	1796	1874	1952	2030	......	......
46	598	672	747	822	897	971	1046	1121	1196	1270	1344	1420	1494	1569	1644	1718	1794	1868	1942	......	......
48	573	644	716	788	859	931	1001	1073	1146	1218	1288	1361	1432	1503	1575	1647	1718	1790	1862	1933	2002
50	550	619	687	756	825	894	962	1031	1100	1169	1238	1307	1374	1444	1512	1581	1650	1718	1788	1856	1924
52	529	595	661	727	793	859	925	992	1058	1123	1190	1257	1322	1389	1453	1520	1586	1652	1718	1785	1850
54	509	573	636	700	764	827	891	955	1019	1082	1146	1210	1272	1338	1400	1464	1528	1591	1654	1718	1782
60	458	516	573	630	687	745	802	859	917	974	1032	1089	1146	1202	1260	1318	1375	1431	1490	1547	1603
66	417	469	521	573	625	677	729	782	834	886	938	990	1042	1093	1146	1198	1250	1301	1354	1407	1458
72	382	430	477	525	573	621	668	716	764	812	860	907	954	1002	1050	1098	1146	1193	1242	1290	1336
78	352	397	441	484	529	573	617	661	703	749	794	838	882	926	968	1013	1058	1101	1146	1190	1234
84	327	368	409	450	491	532	573	614	655	696	736	778	818	860	900	941	982	1022	1064	1105	1146
90	305	344	382	420	459	496	535	573	611	650	688	726	764	802	840	879	917	955	993	1031	1070
96	286	322	358	394	430	465	501	537	573	609	645	681	716	752	788	824	859	895	931	968	1002
102	270	303	337	371	405	438	472	506	539	573	607	641	674	708	742	775	810	843	876	910	944
108	254	287	318	350	382	414	445	478	509	541	573	605	636	669	700	732	764	796	827	860	891
114	241	272	302	332	362	392	422	453	483	513	543	573	603	634	664	694	724	754	784	814	844
120	229	258	286	315	344	372	401	430	458	487	516	545	573	602	630	659	687	716	745	774	802
126	218	246	273	300	328	355	382	409	436	464	491	518	546	573	600	628	655	683	710	737	764
132	208	234	260	287	312	339	365	391	417	443	469	495	521	547	573	599	625	651	677	704	729
138	199	224	249	274	299	324	349	374	398	424	449	474	498	524	548	573	598	623	648	673	698
144	191	215	239	262	287	310	334	358	382	406	430	454	478	501	525	549	573	597	621	645	668

The safe working pressure is found by dividing the above bursting pressures by the factor of safety and multiplying the quotient by the efficiency of the longitudinal joint. Example: Shell 60 in. diam. × ½ in. thick, factor of safety 4, single riveted lap joint efficiency .548. $\frac{917}{4} \times .548 = 125$ lbs.

Cut 87.

GALLONS IN CYLINDRICAL TANKS

Depth in Feet	DIAMETERS IN FEET																
	5	6	7	8	9	10	12	14	16	18	20	25	30	35	40	45	50
1	147	212	288	376	476	588	846	1152	1504	1904	2350	3672	5288	7197	9400	11897	14688
5	734	1058	1439	1880	2379	2938	4230	5758	7520	9518	11751	18360	26438	35986	47001	59486	73440
6	881	1269	1727	2256	2855	3525	5076	6909	9025	11422	14101	22032	31726	43183	56402	71383	88128
7	1028	1481	2015	2632	3331	4113	5922	8061	10529	13325	16451	25704	37014	50380	65802	83281	102816
8	1175	1692	2303	3008	3807	4700	6768	9212	12033	15229	18801	29376	42301	57577	75202	95178	117504
9	1322	1904	2591	3384	4283	5288	7614	10364	13537	17132	21151	33048	47589	64774	84603	107075	132192
10	1469	2115	2879	3760	4759	5875	8460	11515	15041	19036	23501	36720	52877	71971	94003	118972	146880
12	1762	2538	3455	4512	5711	7050	10152	13818	18049	22843	28201	44064	63452	86365	112803	142767	176256
14	2056	2961	4030	5264	6662	8225	11844	16121	21033	26650	32901	51408	74027	100759	131604	166561	205631
16	2350	3384	4606	6016	7614	9400	13536	18424	24066	30458	37602	58752	84603	115154	150405	190356	235007
18	2644	3807	5182	6768	8566	10575	15228	20727	27074	34265	42302	66096	95178	129548	169205	214150	264383
20	2938	4230	5758	7520	9518	11750	16921	23030	30082	38072	47002	73440	105753	143942	188006	237945	293759
25	3672	5288	7197	9400	11897	14688	21151	28788	37603	47590	58753	91800	132192	179928	235007	297431	367199
30	4406	6345	8636	11280	14277	17626	25381	34545	45123	57108	70503	110160	158630	215913	282009	356917	440639
35	5141	7403	10076	13160	16656	20563	29611	40303	52643	66626	82254	128520	185068	251899	329010	416404	514079
40	5875	8460	11515	15040	19036	23501	33841	46060	60164	76144	94004	146880	211507	287884	376012	475890	587518
45	6610	9518	12955	16920	21415	26440	38071	51818	67685	85662	105755	165239	237945	323870	423013	535376	660958
50	7344	10576	14394	18800	23794	29376	42301	57575	75205	95180	117505	183600	264383	359855	470015	594862	734398
60	8813	12691	17273	22561	28553	35251	50762	69090	90246	114216	141006	220319	317260	431826	564017	713835	881278
70	10283	14806	20152	26321	33312	41126	59222	80605	105287	133252	164507	257039	370137	503797	658020	832807	1028157
80	11750	16921	23031	30081	38071	47002	67682	92120	120328	152288	188008	293759	423013	575768	752024	951780	1175037
90	13219	19036	25909	33841	42830	52877	76143	103635	135369	171324	211509	330479	475890	647739	846027	1070752	1321916
100	14688	21151	28788	37601	47589	58752	84603	115150	150410	190360	235010	367199	528767	719710	940030	1189725	1468796

$$1 \text{ Gallon} = 231 \text{ cu. in.} = \frac{1 \text{ cu. ft.}}{7.4805} = 0.13368 \text{ cu. ft.}$$

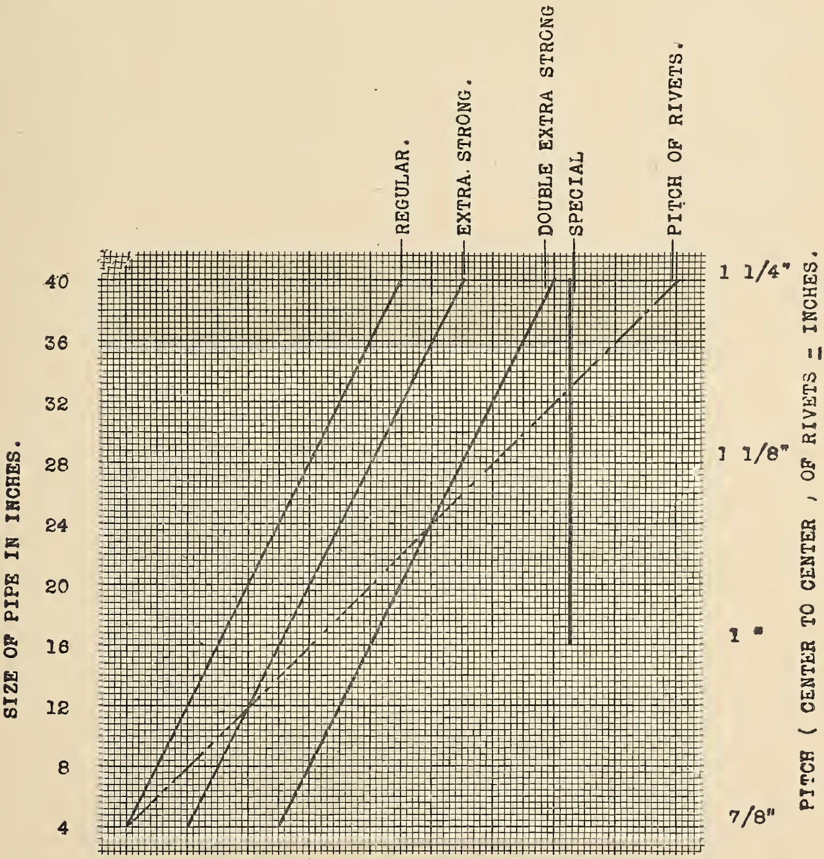
Cut 88.

RIVETED PIPE

Riveted pipe is manufactured with a spiral seam or a straight seam, and in sizes ranging from 3 inches diameter up to 72 inches in diameter. It comes into extensive use for Exhaust steam, Suction pipe, Condenser piping, Compressed air and Vacuum work, and in Water supply, Hydraulic mining, Hydro Power plants, and Dredging.

SPIRAL RIVETED PIPE

Spiral seamed pipe is manufactured in sizes ranging from 3 inch to 42 inches in diameter, the steel used in its manufacture being high grade Tank quality of from 55000 to 65000 pounds tensile strength, and the rivets used in making the seam are usually driven cold, so that they are of high quality annealed special material.



GAGE SHEET	18	16	14	12	10	8	6	3	
In 1/64"	3	4	5	7	9	11	13	1/4"	5/16"
SIZE RIVET	1/8"	3/16	1/4	5/16	3/8	1/2	5/8	11/16	3/4

Cut 89.

In the manufacture of such pipe, a strip of sheet metal is wound into helical shape with one edge overlapping the other for riveting the seam. It is practice to make this metal to metal joint, so that the steel in the outer lap is stretched somewhat, and to offset it slightly in order to make the interior of the pipe as smooth as possible. This seam is the strongest part of such pipe, as has been demonstrated in numerable Bursting tests the metal in the solid sheet failing before the seam gives way.

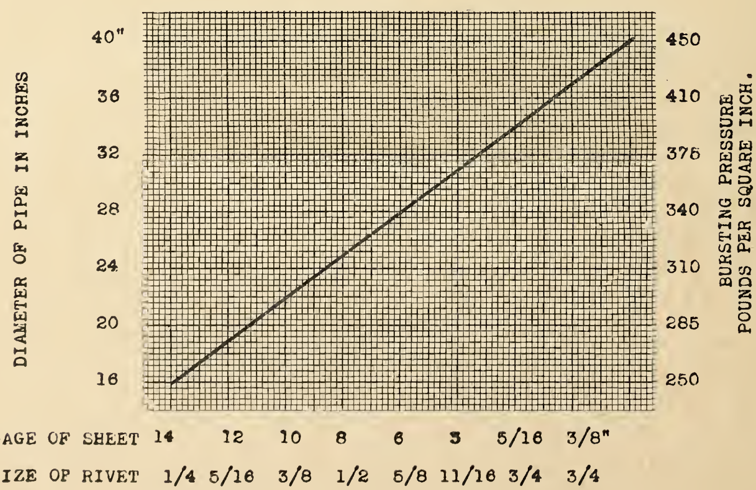
Spiral seams have an efficiency of 100%, and this type of pipe is from, 30 to 60% stronger than the same size of Straight Seam pipe. This is natural as the joints in straight seams are directly proportional to the efficiency of the Lap joints used in their construction.

Cut 89 gives curves showing the rivet spacing, thickness of sheet, and size of rivet as commonly employed in this type of construction. The dash and dot line is used for locating the pitch of rivets.

Flat or Pan Headed rivets are usually employed in this work, and the rivets inserted from the inside when practical, forming a Button or Cone point on the outside. In work employing the opposite, vis rivets placed from the outside in, it is important to make the formed head as flat as possible so as to avoid friction within the pipe.

In flanges for riveted pipe it is an advantage to have the necks of flanges fitting onto the pipe as thin as possible so that flanges and pipe can be fitted together and the rivet holes punched through both pieces at one time. Drilling of Flange neck, and of pipe to template is liable to error, and the holes not always fair, besides being expensive.

APPROXIMATE BURSTING PRESSURE OF STRAIGHT SEAM PIPE.
THICKNESS OF SHEET and SIZE OF RIVET.



Cut 90.

STRAIGHT SEAM RIVETED PIPE

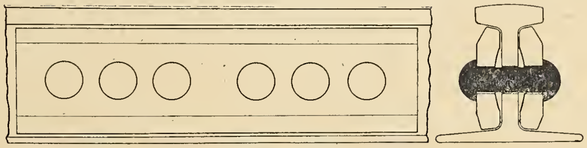
This type of pipe is not as strong as Spiral Riveted pipe for the same thickness of sheet, but it can be made easier in large sizes. In this work the Roundabout seams are single riveted, while the Longitudinal seams are double riveted, the rivets being staggered in arrangement. The lap on these joints should be such that from the center of the Rivet to the edge of the plate is never less than 1½d., and on Flange connections it should be from 2 to 2½d. Rivets in Flange connections to the pipe proper should be pressure driven. Straight seam pipe has practically the same uses as given for Spiral pipe. The bursting pressure for this type is given in Cut 90, with gage of sheet and size of rivet commonly employed.

In using any riveted pipe a factor of safety of 4 should be used on the Theoretical Bursting Pressures given for Working Pressure on ordinary work. When the pipe is subjected to Hydraulic use and Water hammer might occur the factor should be increased to 6 or even higher.

RIVETS IN SPLICE CONNECTIONS ON RAILS

In the introduction of the welded Rail joint used extensively in Street Railway work, on account of the better electrical characteristics, rivets have taken the place of the Splice bolts usually used. This gives a more rigid joint, and after the welding there is no play in such a joint such as might occur through bolts coming loose due to the working of the joint.

Cut 91 illustrates such a joint, and the following table gives the diameters of rivets that should be used for the replacing of bolts in welded work or permanently connected Splice bar to Standard rails.



Cut 91.

Size of Rail.	Rivet Diameter.	Number of Rivets per Joint
90 to 100.	1″	6.
75 to 90	⅞″	6.
40 to 75	¾″	4.
30 and 35	⅝″	4.
12 to 30	½″	4.
8 and 10	⅜″	4.

Such joints are in satisfactory service in Philadelphia, Cleveland, and other cities.

RIVETS FOR SHEET METAL WORK

This class of rivets are made from high grade soft steel, and for tin work are tinned. They are made flatheaded, button headed or countersunk. The Standard countersink for this class of work is 80°.

Such rivets are not ordinarily subject to specific tests, but when required the tests are as follows:

Cold Test.—Rivets shall be flattened to $\frac{1}{8}$ of their original diameter then bent through 180° and flattened on themselves, this to be accomplished without showing flaws, crack or other defects.

Hot Test:—Rivets shall be heated to a red heat and flattened, then reheated and bent 180° flat on themselves without showing flaws.

This class of rivets are packed in cardboard boxes, one pound to a box, unless otherwise specified, the box marked with brand and the size of the rivets.

The following tables shows the sizes of these rivets, the shanks of which are given in Wire sizes. Cut 92 gives the heads.

RIVETS FOR SHEET METAL WORK

SIZE.	FLAT HEAD.			
	Size of Wire.	Length under Head.	Diameter of Head.	Thickness of Head.
8 Ozs.	.092	$\frac{5}{32}$″	$\frac{15}{64}$″	.025
10	.095	$\frac{11}{64}$″	$\frac{15}{64}$″	.025
12	.105	$\frac{3}{16}$″	$\frac{15}{64}$″	.025
14	.109	$\frac{3}{16}$″	$\frac{1}{4}$″	.025
1 lb.	.111	$\frac{13}{64}$″	$\frac{9}{32}$″	.028
1¼	.120	$\frac{7}{32}$″	$\frac{9}{32}$″	.032
1½	.130	$\frac{15}{64}$″	$\frac{21}{64}$″	.032
1¾	.134	$\frac{1}{4}$″	$\frac{11}{32}$″	.035
2	.144	$\frac{17}{64}$″	$\frac{11}{32}$″	.035
2½	.148	$\frac{9}{32}$″	$\frac{11}{32}$″	.042
3	.160	$\frac{5}{16}$″	$\frac{3}{8}$″	.042
3½	.165	$\frac{21}{64}$″	$\frac{25}{64}$″	.049
4	.176	$\frac{11}{32}$″	$\frac{13}{32}$″	.049
5	.185	$\frac{3}{8}$″	$\frac{13}{32}$″	.058
6	.203	$\frac{25}{64}$″	$\frac{27}{64}$″	.058
7	.215	$\frac{13}{32}$″	$\frac{7}{16}$″	.065
8	.224	$\frac{7}{16}$″	$\frac{1}{2}$″	.065
9	.233	$\frac{29}{64}$″	$\frac{35}{64}$″	.072
10	.238	$\frac{15}{32}$″	$\frac{35}{64}$″	.072
12	.259	$\frac{1}{2}$″	$\frac{9}{16}$″	.083
14	.284	$\frac{33}{64}$″	$\frac{37}{64}$″	.083
16	.300	$\frac{17}{32}$″	$\frac{19}{32}$″	.083

SMALL RIVETS

Cut 92.

1. Round Head.
2. Pan Head.
3. Flat Countersunk Head.
4. Cone Head.
5. Oval Countersunk Head.
6. Oval Head.
7. Flat Head.
8. Truss Head.
9. Wagon Box Head.

COUNTERSUNK.

Size of Wire.	Diameter of Head.	Thickness of Head.
.083	.158	.043
.095	.182	.050
.109	.210	.058
.120	.232	.064
.134	.260	.072
.148	.288	.085
.165	.322	.090
.180	.352	.099
.187	.367	.103
.203	.398	.112
.220	.432	.122
.238	.468	.132
.250	.492	.138
.259	.510	.144
.284	.560	.158
.300	.592	.168
.312	.617	.175
.343	.680	.193
.375	.742	.211
.437	.867	.247

CHAPTER XII

HEATING OF RIVETS, FURNACES AND FUELS

When steel is heated for some length of time at a temperature above that of softness and just below its melting point, it becomes coarsely crystaline, the crystals have weak cohesion, this condition being called burnt steel. If rivets in this condition are driven, they will break up as they have no toughness, and when cold they are very brittle, and may be broken off short and the fracture being bright and glistening. The carbon in such steel does not appear to have been burned out, when chemical analyses are made, nor is any oxygen absorbed by burnt steel, so properly speaking the condition really is not one of burning at all, the bad effects being apparently caused by the crystalization. Although burnt steel may be restored by very slow annealing, it should never be attempted as it is only a trick of the metallurgist, and the value of restored burnt steel is still very doubtful.

In Section II, under a description of the manufacture of steel mention was made of the taking up of gases by steel, and the subsequent release of these gases on cooling the steel. An actual analysis of the gases occluded in steel, and which gases were obtained by a heating of the steel in question for 36 hours in a vacuum, at a temperature of 1800° Farenheit was:

Carbon Dioxide,	CO_2,	0.48%
Hydrogen,	H_2,	49.62%
Carbon Monoxide,	CO	48.05%
Methane,	CH_4,	0.40%
Nitrogen	N_2,	1.45%

In these experiments it was determined that approximately 10 times the volume of the steel was represented by the gases given off, and the steel taken was of the soundest obtainable, and cut from an ingot so that the sample contained no blow holes. In unsound steel the volume of gas from steel seems to be lower in quantity and on repeated tests amounted approximately 5 volumes of the steel taken, or only 50% of the amount found in sound steel.

It is a foregone conclusion that gases are in steel, and unfortunately the opinion of certain persons regarding the subject are not based on a thorough knowedge of the subject. For such persons edification it might be added that steel looses the above mentioned gases, as the temperature of cold steel is raised, and approximately as follows:

Hydrogen is given off at as low as 650° Farenheit.

Hydrogen is given off at the fastest rate at 1250° Farenheit.

Hydrogen evolution drops off from this point and is complete at a temperature of 1800° Farenheit.

Up to a temperature of approximately 1000° Hydrogen represents 90% of the gases given off.

At 1000° Carbon Monoxide begins to come off.

Carbon Monoxide is at a maximum at 1400° Farenheit.

Carbon Monoxide evolution then tapers off and is at a minimum at a temperature of 1600° Farenheit.

While the above gases have been found in steel, good and bad, and as stated all steel contains gases, the absorption of gases by hot steel is not so easily effected. Hydrogen is however absorbed by hot steel at a temperature of 1800°, and in the Nacent state, such as in Cold Pickling can be readily taken up by steel. Manganese in steel and Nickel seem to favor the absorption of gases, and Carbon opposes it, while Silicon seems to retard the evolution of gases on heating. In as much as rivets prior to use are given two heatings, any chance of deletarious gas occulsion would not occur. While the heading temperature may approximate 1600° in many cases, slow cooling follows, which is ideal for the liberation of all gases, and in the next heating for driving, at approximately 1250° Farenheit, becomes an additional safeguard as it is at this temperature as noted above that the liberation of Hydrogen is the greatest.

Natural gas is the ideal fuel, and an idea of the quantity used can be formed from the fact that in Ohio, over 2500 Industrial concerns are using this fuel and consuming over 150,000,000,000 cubic feet per annum. With the high calorific power, and uniform composition, which is practically pure Methane, or the following analysis may be noted:

Natural Gas

Carbon Monoxide.	CO.	1.5
Methane,	CH_4	94.0
Hydrogen,	H_2	.0
Nitrogen, Oxygen, etc	N_2	4.5
B.T.U. per cubic foot,		1030

It might here be stated that the S. Severance Manufacturing Company uses Natural gas in the manufacture of its rivets, and believes that thereby a superior rivet is produced.

In order to make this discussion about gas, steel and fuel complete, a word should be given about High Sulphur Fuels and Steel. The injurious effects of sulphur on metal have not been substantiated, and when injurious it must exist as previously indicated as Manganese Sulphide. No Manganese Sulphide could possibly be formed by sulphur taken up by steel from the fuel used to heat it. Fuel oil naturally is high in sulphur, and as high as 3% sulphur is common, but no concern using such material is

experiencing any trouble from that element entering the metal. Much of this trouble if it exists is due to the incomplete combustion of the fuel and to poor design of the heating furnace using this fuel. Proper methods of burning, and adequate combustion chambers will positively eliminate all troubles of this sort.

HEATING RIVETS

In heating rivets the heater should know his business. Good work as far as a properly heated rivet is concerned can be obtained from a coal or coke fire, although in this type of fire there is danger in overheating of rivets due to their being covered, and scaling is naturally excessive.

Oil furnaces and gas furnces heat rivets uniformly, and the flame is directed onto the work, tending to keep down scale to the minimum. Indirect heat ovens are also very successful, and are more economical in gas consumption.

Furnaces with a magazine for holding cold rivets, and into which a handful or a keg full of cold rivets can be emptied, these feeding down gradually into the heating chamber are to be given serious consideration by any concern desiring to get the maximum out of its apparatus.

Portable rivet heaters are used to some extent, which are nothing more than a furnace mounted on a truck, and with a fuel pipe that can be attached to a source of supply.

The performance of reliable rivet furnaces is given as follows:

Type of Furnace.	Heating Space. L W H	Oil per Hour.	Rivets Heated per Hour.
Oil Burner..............	14″ × 12″ × 5″	2 Gallons.	500 ⅞″
Gas Furnace............	7″ diameter.	50 Cu. Ft. Gas.	200 ⅜″
Gas Furnace............	12″ × 12″	100 Cu. Ft. Gas.	400 ⅜″
Oil Burners.............	36″ × 15″	3 Gallons Oil.	600 ¾″x3

The following points about furnaces in general should be noted.

1. By having twin hearths, or even four hearths in the same furnaces that number of riveting gangs can be served by the same furnace with a resulting economy in fuel.
2. Hopper feeds are economical, and permit of the maximum number of full heated rivets out of a furnace, and preheat the cold rivets by the exhaust gases.
3. Gas fired furnaces should preferably be insulated by cork or insulating bricks to secure maximum economy.
4. Oil burning furnaces if properly regulated give a non-scaling flame.
5. With a ombustion chamber under the hearth indirect heating is accomplished, and by thus heating above or below, a soft, soaking, non-scaling heat is produced, which is ideal for the heating of rivets.

Cost is not always a fair guide on performance, as satisfactory heating is of first importance. In a test recently conducted at the Newport News Shipbuilding Company, rivet heating by gas and oil were compared, and with the following results:

Fuel.	Unit Cost.	Rivets Heated.	Time Heating.	Cost.
Oil........	6c per gal.	400 Pounds.	44 Minutes.	52.5c
Gas.......	55c per 1000	400 Pounds.	57 Minutes.	53.5c

Gas heated rivets considered best because no scale was present, and were said to stay hotter than oil heated, and thus could be driven longer, due to being heated evenly all the way through. Oil heated rivets were extremely hot on the outside but not as hot in the center and hence cooled more quickly.

MANIPULATION

Good work by a riveting crew or gang depends fundamentally on properly heated rivets. With a good furnace, either oil or gas fired, the heater can give his undivided attention to regulating the forge so that there will be no burned or underheated rivets, irrespective of the speed at which the gang works.

Proper operation tends towards regularity, and productive of properly upset, tight, full headed rivets. The cooling contraction then is more uniform and calking reduced to a minimum.

Rivets should be heated slowly and uniformly, and not soaked after they have come to heat, as soaking tends towards decarburization.

Sparkling hot steel rivets should be discarded. Steel at the melting point flows away rapidly, and slim points result, which will not head properly. The heater should not heat rivets faster than the gang can take care of them. A burning rivet gives off sparks, but is injured even before this indication takes place.

The self-feeding furnaces mentioned permit of a heating rivet being in sight at all times, and an adequate supply of properly heated rivets at all times. Rivets should be put into a furnace head first, not because the head is larger than the point, and thus would require more heat to uniformly heat, but because the point can be tonged easier than the head. It does not matter which end is put into a furnace first as far as heating is concerned. Steel heats up at the rate of 100° per inch per hour when in ingot form, and the dimensions of a rivet are infinitesimal in comparison, but is heated from the surface inward in all directions hence the head or point does not enter into the argument.

TEMPERATURES FOR DRIVING

Hand, Pneumatic, and Pressure riveting require different ranges in heat, due to the very nature of the driving. Hand and pneumatic driving require a hotter rivet than does hydraulic, or Pneumatic Machine driving. Small rivets cool off quicker than large ones and thus they should be heated to a higher temperature.

Heat Hand Driven rivets to a light yellow heat, or 1900° Farenheit.

Heat Pneumatic Hammer Driven Rivets to a full bright cherry red heat, or approximately 1450° Farenheit.

Heat Pressure Driven Rivets to a dark cherry red, sometimes called a dark red, or to approximately 1200° Farenheit.

Pressure should be held on a Pneumatic or Hydraulic Pressure Riveter until the rivet has set, and a pressure out of proportion to the size of the rivet should not be used. Incidentally the plates in contact with rivets, whether pressure, pneumatic hammer, or hand driven should not get too hot, and everybody knows the danger from blue heated plates. Blue hot rivets should never be hammered under any condition.

The proper pressures to be applied to rivets when pressure driven are approximately as follows:

Size of Rivets.	Pressure in Tons.
$\frac{1}{2}''$	20
$\frac{9}{16}''$	25
$\frac{5}{8}''$	28
$\frac{11}{16}''$	34
$\frac{3}{4}''$	40
$\frac{7}{8}''$	50
$1''$	64
$1\frac{1}{8}''$	80
$1\frac{1}{4}''$	100

CHAPTER XIII

PUNCHING PLATE AND DRIVING RIVETS

In punching plate the intensity of the pressure required for perforation of the plate, increases with the thickness of the plates, and thus lateral flow of metal is more likely to occur the thicker the plate. The hole made by punching is always slightly conical due to the clearance between the punch and die, which is commonly 1/32 of an inch, and for this reason Swell Necked rivets are used extensively, the taper to the neck fitting into this taper in the hole.

The urgent need for ships brought improvement in punching machines, and one well known design of punch and table operated by one man, is capable of punching from 13/16″ up to 1 1/16″ diameter holes in steel plate from 9/16″ up to $1\frac{1}{8}$″ in thickness at the rate of from 420 to 670 holes per hour. The plate material which can be handled runs from 5 feet to 8 feet wide and from 24 feet to 30 feet long. An average of 4000 holes in 9 hours has been obtained with such machines.

Experiments have demonstrated that the resistance to punching is approximately the same in value to tensile strength, and thus for punching calculations 50,000 pounds per square inch can be taken, and for an appreciation of the force necessary for punching the following consideration is quoted:

Force of Punching $= \pi \, d \times t \times 50000.$

Where d $=$ Diameter of the Hole in inches.

t $=$ Thickness of the plate in inches.

$\pi = 3.1416.$

And for a $\frac{3}{4}$″ hole in $\frac{1}{2}$″ plate, would be:

Force $= 3.1416 \times \frac{3}{4} \times \frac{1}{2} \times 50000.$

$=$ 58900 lbs. for punching one hole.

In punching multiple holes the force required for perforation may run into very large figures.

In punching a good ductile plate, the area of metal around the hole, probably is not injured at all, but when plates are more or less hard and so called steely, the effect of punching may cause serious local injury.

For this reason holes are punched small and reamed to size to remove any injured metal.

A drilled hole undoubtedly is stronger than a punched hole, but it may have sharp corners that are a detriment as they may act like a shear edge on the rivet. A punched hole in metal may have all danger from overstrain on the metal around the hole removed by annealing the plate, but it is common practice to ream to size removing the injured metal. In punching the depth of injury is under $\frac{1}{8}$″, and by reaming even less than that amount any incipient cracks will be cut out.

Probably no shop fabricating steel is operating their drills, when drilling solid at the proper speed and feed, and the following table is given as a reliable one in this respect.

SPEEDS AND FEEDS IN DRILLING MILD STEEL

Size	R. P. M.	Feed Per Rev.	Feed Per Min.
$\frac{1}{16}$	2445	.002	$4\frac{57}{64}$
$\frac{1}{8}$	1800	.003	$5\frac{1}{2}$
$\frac{3}{16}$	1290	.003	$4\frac{7}{8}$
$\frac{1}{4}$	700	.005	$3\frac{1}{2}$
$\frac{5}{16}$	550	.005	$2\frac{3}{4}$
$\frac{3}{8}$	358	.005	$1\frac{51}{64}$
$\frac{7}{16}$	300	.006	$1\frac{51}{64}$
$\frac{1}{2}$	270	.006	$1\frac{5}{8}$
$\frac{9}{16}$	230	.007	$1\frac{39}{64}$
$\frac{5}{8}$	216	.007	$1\frac{33}{64}$
$\frac{11}{16}$	190	.008	$1\frac{33}{64}$
$\frac{3}{4}$	185	.008	$1\frac{31}{64}$
$\frac{13}{16}$	166	.009	$1\frac{31}{64}$
$\frac{7}{8}$	149	.010	$1\frac{31}{64}$
$\frac{15}{16}$	142	.010	$1\frac{27}{64}$
1	134	.010	$1\frac{11}{32}$
$1\frac{1}{16}$	128	.010	$1\frac{9}{32}$
$1\frac{1}{8}$	115	.011	$1\frac{17}{64}$
$1\frac{3}{16}$	113	.011	$1\frac{15}{64}$
$1\frac{1}{4}$	107	.011	$1\frac{11}{64}$
$1\frac{5}{16}$	102	.011	$1\frac{1}{8}$
$1\frac{3}{8}$	93	.012	$1\frac{7}{64}$
$1\frac{7}{16}$	92	.012	$1\frac{7}{64}$
$1\frac{1}{2}$	90	.012	$1\frac{5}{64}$

Cut 93.

RIVETING

Hand riveting is slow, and has a tendency to form a shoulder before the rivet completely fills the hole. In hand riveting the tail of the rivet is held up, while the point is headed by two riveters working with hammers, the head either being made conical with the hammers alone, or finished by means of a snap, shaped to the desired head.

Pneumatic hammers perform good work, requiring compressed air at approximately 100 pounds pressure for their operation. With this type of riveter it is necessary to have the plates firmly bolted and drawn up as no pressure is exerted tending to draw the plates together. By describing a large circle on the outside of a head, it is possible to make a short rivet look satisfactory, and inspection should be careful to see that this dishonesty is not practiced.

Riveting hammers are made in the following sizes:

Capacity in Rivets.	Blows per Minute.	Cubic Feet Air used per Minute.	Air Hose Connection.	Weight of the Hammer, complete
1/4"	1750	18	1/4"	11 3/4 lbs.
3/8"	1542	20	1/4"	12
1/2"	1272	22	1/4"	12 1/2
3/4"	1000	25	3/8"	20
7/8"	760	25	3/8"	23
1 1/8"	700	25	3/8"	25
1 1/4"	620	25	3/8"	26
1 3/8"	800	28	3/8"	26
1 1/2"	700	30	3/8"	31 1/2

Pressure Machine Riveting causes the pressure on a rivet to be applied gradually over the entire rivet, does not tend to form a shoulder, and the hole is completely filled before the head is formed. The machines are operated by the pressing of two dies, connected by means of a lever, toggle or other system of levers to Steam, Hydraulic or Pneumatic actuated pistons. Steam operated riveters are apt to start with a jerk, hence applying uneven pressure, while hydraulic are apt to be slow in reaching the point of action, Pneumatic coming up quicker to the work. It has been mentioned that the Holder On is quite as important as the Riveting Mechanism, and compressed air Holder Ons, and other power devices are to be preferred to Dolly Bars, and hand held long handled hammers.

RIVETING MACHINES

The Jaw Riveter, or as it is sometimes called in shop language "Bull Riveter," is a compression machine of the toggle leverage type and drives a rivet by a single squeeze. Such machines are used extensively for general structural work. Air pressure, or steam, at from 80 to 100 pounds pressure is required for operation.

A Compression Lever Riveter is made with an Angle Lever and is used on Beam and Girder work for Bridges in particular. The rivet head is formed by compression, levers acting on a fulcrum containing at one end of the levers the Rivet dies, and the other end connected to Toggle Links.

Alligator Riveters, made on the Compression Lever principle are used extensively on Railway Car construction. Properly suspended this type of machine can operate in the vertical or horizontal postion, and the angles in between.

One well known make of Boiler Riveter consists of a machine having two long arms on the ends of which is a cylinder with a Piston hammer, one end of the hammer being cupped to form the head of the rivet. On the other arm are the Holding On dies, with a proper anvil to absorb the hammer blows. The rivet head is formed by a succession of quick uniform blows, yielding accurate work. Plates are squeezed together by the action of the long leverage arms, the pressure being approximately 5000 pounds on this leverage, before the hammer commences to work. This pressure is maintained during the riveting, and for Boiler, Tank, Smoke stack, and Riveted Pipe work the machine is good.

In another well known machine two motions, a toggle action at the beginning of a stroke, followed by a lever action at the completion of a stroke, are employed. This permits of leeway in the adjustment of dies forming tight fully driven rivets with a comparatively rough adjustment of dies. On account of this peculiar motion driving of cold rivets is done well, as time is given for flow of metal to take place and fill the hole completely, and then forming the head on the leverage action. Such machines operate on air pressure at approximately 100 pounds.

Hydraulic Riveters are compression riveters operated by hydraulic pressure, requiring an accumulator for proper maintaining pressures and adjustment to suit different sizes of rivets. The water pressure involved amounts to between 1000 to 1500 pounds, requiring Pressure pumps, Hydraulic piping, valves and accumulator. The lighter weight less expensive air operated machines described above are taking the place of the heavy expensive hydraulic riveters.

Electrical Riveting Machines. A machine is on the market that heats and drives rivets by Electrical power. The Cold rivet is inserted between plates and a heating electrode brought down in contact with the rivet, heating the rivet to the usual driving temperature. This electrode is then swung out of the way and a Pressure Riveting head containing a snap brought over the heated rivet. Gearing exerts uniform pressure on the rivet point forming the head. Since such rivets heated electrically heat from the core outward they are easy to shape, and thus tends to make a good fit. Rivets for electrical heating must be free from scale, and must be tumbled or sand blasted before driving. Such machines are made to take from $\frac{1}{8}''$ rivets up to rivets as large as $1\frac{1}{2}''$ in diameter.

CAPACITY OF RIVETERS:—The Toggle, Lever, Air Operated machines described above, have a capacity as high as 2000 $\frac{3}{4}''$ rivets driven per hour. The sizes of such machines are as follows:

Pressure on the Rivet.	Capacity in Rivet size.	
20 tons.	$\frac{1}{2}''$ Structural.	
30 tons.	$\frac{3}{4}''$ Structural.	$\frac{1}{2}''$ Steam.
50 tons.	$\frac{7}{8}''$ Structural.	$\frac{3}{4}''$ Steam.
70 tons.	$1''$ Structural.	$\frac{7}{8}''$ Steam.
100 tons.		$1\frac{1}{8}''$ Steam.
125 tons.		$1\frac{1}{4}''$ Steam.
150 tons.		$1\frac{1}{2}''$ Steam.

Riveting Recorders: There is danger as has been mentioned, of releasing the pressure on a rivet in pressure riveting, prior to proper setting of the rivet. That is the pressure on the die may be released before the rivet has had time to cool. In such an event the plates may spring apart to such an extent that the shrinkage of the rivet in cooling will not pull the plates together enough to insure a tight joint. A Recorder is in use in Europe which operates by the piston pressure and a control valve connected to a gage with red and black pointer. The pressure is kept constant for a predetermined number of seconds when the red pointer indicates that the pressure can be released, and the pointer returns to zero. Graphic records are also made with the instrument.

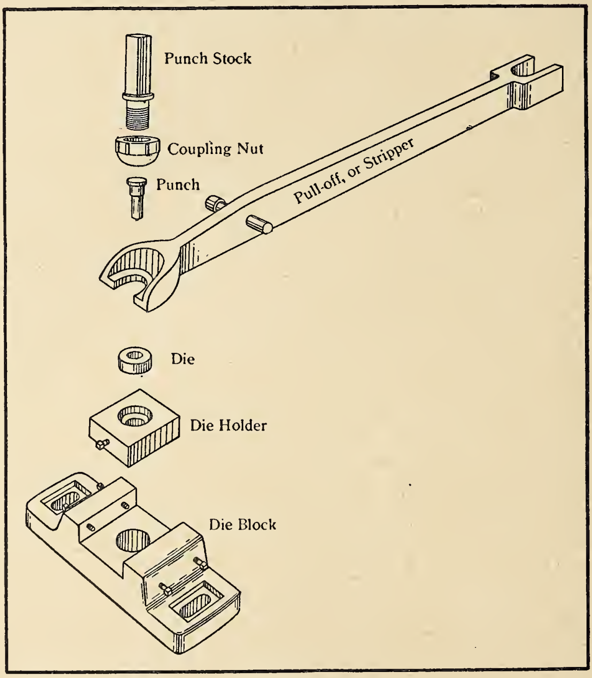
Cold Riveting: Plates up to $\frac{3}{8}''$ in thickness, and using $\frac{5}{8}''$ rivets are sometimes cold headed. Such rivets should be annealed prior to use. To drive Cold Headed rivets the following pressures should be used:

Size of Rivet.	Pressure on Rivet.
$\frac{1}{4}''$	12 tons.
$\frac{5}{16}''$	15 tons.
$\frac{3}{8}''$	22 tons.
$\frac{1}{2}''$	31 tons.
$\frac{5}{8}''$	56 tons.

Operation of Riveters: In die adjustment and the operation of riveters, care should be exerted not to crush or scallop the plate in front of a rivet. Finns and washers should not be formed around the head of a rivet, and if plates are not closely bolted together before riveting is done, a washer may form between the plates.

PUNCHES, DIES AND SNAPS

PUNCHES: A set of Punching tools consists of the following, as illustrated in Cut 94.

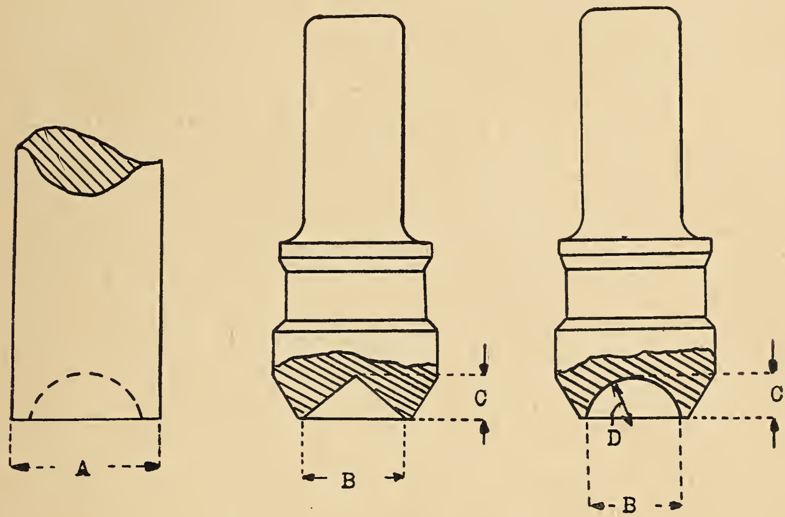


Cut 94.

The Die holder holds the die, and the Punch Stock with Nut holds the punch. A gage bolts to the frame of the machine and indicates distance to edge of the plate being punched. The Stripper straddles the punch and pulls the work off the punch after it has gone through the plate. The Stripper is adjustable to various thicknesses of metal.

STANDARD RIVET DIES AND SETS

The following are representative standards for Rivet dies, Cut 95 illustrating the Standard of the American Bridge Company, and the Standards for Cone Head Rivet and Button Head Rivet snaps.



Cut 95.

AMERICAN BRIDGE COMPANY

Standard Rivet Dies

For Rivet.	A.
$\frac{5}{8}''$	$2''$
$\frac{3}{4}''$	$2\frac{1}{4}''$
$\frac{7}{8}''$	$2\frac{1}{2}''$
$1''$	$2\frac{3}{4}''$
$1\frac{1}{8}''$	$3''$

Cone Head Snap

Area B = Area Rivet × 3.
C = Diameter of Set × .43.

Button Head Snap

Area B = Area Rivet × 2.5.
C = 4 B.
D = ½ B × 1.024.
Length of Rivet to form head = .45B.

Diameter of Rivet.	B.	C.	Diameter of Rivet.	B.	C.	D.
1/8	7/32	3/32	1/8	3/16	5/64	3/32
3/16	5/16	9/64	3/16	5/16	1/8	5/32
1/4	7/16	3/16	1/4	3/8	5/32	3/16
5/16	35/64	15/64	5/16	1/2	13/64	1/4
3/8	41/64	9/32	3/8	19/32	15/64	5/16
7/16	3/4	21/64	7/16	11/16	9/32	23/64
1/2	55/64	3/8	1/2	25/32	5/16	13/32
9/16	31/32	27/64	9/16	7/8	11/32	29/64
5/8	1 3/32	15/32	5/8	1	13/32	33/64
11/16	1 3/16	33/64	11/16	1 3/32	7/16	9/16
3/4	1 19/64	9/16	3/4	1 3/16	31/64	39/64
13/16	1 13/32	39/64	13/16	1 9/32	33/64	21/32
7/8	1 33/64	21/32	7/8	1 3/8	35/64	45/64
15/16	1 5/8	45/64	15/16	1 15/32	19/32	3/4
1	1 47/64	3/4	1	1 19/32	41/64	13/16
1 1/16	1 27/32	51/64	1 1/16	1 11/16	43/64	55/64
1 1/8	1 61/64	27/32	1 1/8	1 3/4	45/64	57/64
1 3/16	2 1/16	57/64	1 3/16	1 7/8	3/4	31/32
1 1/4	2 11/64	15/16	1 1/4	2	51/64	1 1/32
1 5/16	2 9/32	63/64	1 5/16	2 1/16	53/64	1 1/16
1 3/8	2 3/8	1 1/32	1 3/8	2 3/16	7/8	1 1/8
1 7/16	2 31/64	1 1/16	1 7/16	2 1/4	29/32	1 5/32
1 1/2	2 19/32	1 7/64	1 1/2	2 5/16	59/64	1 3/16
1 9/16	2 45/64	1 5/32	1 9/16	2 7/16	31/32	1 1/4
1 5/8	2 13/16	1 13/64	1 5/8	2 9/16	1 1/32	1 5/16

STEEL FOR DIES AND SNAPS AND PUNCHES

It pays to have quality tool steel dies and punches, and the following data may be of interest. General lack of quality in steel used for these tools and of poor heat treatment are responsible for poor life of tools. A consumer of these tools best find out details of both of these features as effecting his punches, dies and snaps. When driving hot rivets in large number the life of sets may be increased if they are allowed to cool at intervals. Thus extra sets should be provided for riveters. The following are actual results in practice.

Ordinary Cast Steel Dies....... 4000 rivets each set.

High Speed Dies.............. 50000 rivets each set of dies.

High Speed Steel Dies..........180000 rivets driven with four pair.

Vanadium Steel Riveting Hammer Dies. In continuous service for 14 months, driving rivets in Shipbuilding work.

Carbon Steel Dies are apt to break in the shank, when used with Pneumatic hammers, due to crystalization of the steel due to vibration.

Chrome Vanadium Tool Steel Punch and Die on 5/16″ hole lasted for 4422 holes, on 13/16″ holes lasted 4402 holes, and on 13/16″ holes lasted 5453 holes.

CHAPTER XIV

MISCELLANEOUS DATA IN CONNECTION WITH RIVETS—USEFUL TABLES

HIGH SULPHUR RIVETS

Dr. John Unger, of the Carnegie Steel Company made an exhaustive test covering experimental rivets containing varying amounts of sulphur, with the following results:

Heat.	Carbon	Manganese.	Phosphorous.	Sulphur.
1	.09	.43	.012	.030
2	"	"	"	.031
3	"	"	"	.050
4	"	"	"	.060
5	"	"	"	.090
6	"	"	"	.116
7	"	"	"	.140
8	"	"	"	.160
9	"	"	"	.180
10	"	"	"	.250
11	"	"	"	.254

Rivets $\frac{3}{4}''$ by $2''$ were made, and test rivets were subjected to the following tests.

1 Shank Bent Cold 180° Flat.

2 Hot Flattened then Bent Cold.

3 Hot Flattened.

4 Hot Upset.

5 Cold Upset.

6 Hot Flattened.

Shearing test, using 2 rivets of each grade riveted into plate, so that the holes 13/16″ were 2″ from the edges of the plate, the rivets being machine driven.

Heat.	Sulphur.	Tests 1 to 6 inclusive.	Shearing Strength. Pounds per square inch
1	.030	All O.K.	48900.
4	.060	"	48300.
5	.090	"	48800.
7	.140	"	46700.
8	.180	"	47400.

These results would lead to the belief that sulphur is probably not as harmful as we suppose.

MILD STEEL AND HIGH TENSILE STEEL RIVETS COMPARED

A test was run by the Japanese Naval Department to determine the merits of rivets made from these two grades of steel, and valuable findings resulted. The steels used were as follows:

Steel.	Carbon.	Manganese.	Sulphur.	Phosphorous.	Tensile Strength.	Elongation.
Mild Steel.....	.21	.46	.039	.011	56000.	31%
High Tensile...	.41	.51	.039	.022	89500.	20%

Effect of Finishing Temperature: The tensile strength of mild steel was not effected by the finishing temperature but the elongation was, being best at a temperature of 1300° F., and worst at a temperature of 1500°.

The tensile strength of high tensile steel was not effected and the elongation was best at 1500°F.

The shearing strength of rivets was invariably greater than the shearing strength of the raw material from which they were made.

The recommended driving temperatures from the results of the tests were:

Rivets of High Tensile Steel drive at 1800° F., Machine driven.
Rivets of Mild Steel drive at 1900° F., Machine driven.
Mild Steel, Hand or Pneumatic Hammer driven at 2200° F.
High Tensile Steel Hand or Pneumatic driven at 2100° F.

Explosive Tests: In an explosive test, high tensile and mild steel rivets were stressed by exploding powder in a closed chamber, the high tensile showing marked superiority. Results of the test caused recommendation of employing thicker heads than ordinary practice and high tensile steel.

LOCATION OF UPSETTING IN NECK OF RIVET IN DIFFERENT TYPES OF DRIVING

Upset by hand, stoutest section was always close to hammered end.

Upset by Pneumatic hammer, nearer the middle, and holes better filled than in hand riveting.

Upset in Hydraulic riveter, holes best filled of any. Rapid cooling of head of rivet and ends permits swelling in middle of shank.

Tightness of Joints: Joints with 1″ and $1\frac{1}{8}$″ rivets, connecting three thicknesses of 1″ plate, in their order of merit were:

Riveting.	Method.
Both Ends Countersunk....	Hydraulic, Hand, Pneumatic.
Neither End Countersunk..	Hydraulic, Pneumatic, Hand. (Hand being markedly inferior to Hydraulic or Pneumatic).

Joints with two thicknesses of plate gave the relative inferiority of Hand Driven rivets as very slight.

LONG RIVETS: By reaming long holes to a hyperbolic contour, this test demonstrated that long rivets could be used with good results.

NICKEL STEEL JOINTS: Dr. E. Preuss conducted elaborate tests on Nickel Steel rivets, and on Nickel Steel rivets in joints they were found to be from 2 to $2\frac{1}{4}$ times as strong as Carbon Steel rivets of the same size.

SLIPPING OF PLATES: As far as slip is concerned Nickel Steel and Carbon Steel rivets were apparently equal. In tests conducted at the University of Illinois Slip was found to be a function of workmanship as much as any thing else, though contractability and gripping properties of rivets have an influence. In these tests painting a joint with red lead, graphite paint, and unpainted resulted in slip occuring very close together at loads within ordinary working shearing stress of rivets, and the graphite paint giving a lower value than red lead, and red lead lower than unpainted. Dr. Preuss determined that the slipping of a Butt joint is greater than a Lap joint of the same ultimate breaking strength.

FORMING HEADS ON NICKEL STEEL: Rivets require approximately 25% greater pressure in heading when made of Nickel steel, as compared to ordinary mild steel rivets.

CORROSION TESTS: Immersing Nickel steel and Wrought Iron Riveted joints in Sea water for two months, resulted in the Nickel steel joint loosing nearly twice as much weight as a wrought iron riveted joint. The actual results were:

Nickel Steel	Rivets, in Joint.	Loss in weight	= .0043%
Wrought Iron	Rivets, in Joint.	Loss in weight	= .0021%

EFFECT OF CAUSTIC ON RIVETS AND JOINTS

Caustic liquids apparently have a bad effect on tanks and riveted containers in general. Slacking back of the rivets and the calking edges cause leaks, and due to the embrittling effect of Caustic on steel Sheet will ultimately develop cracks. Apparently Hydrogen is absorbed by steel where immersed in Caustic, this leading to the embrittling effect.

ELIPTICAL RIVETS

Since in theoretical design the value P — D, is used as a basis for values, it is apparent that if rivets were made eliptical, and placed with their minor axis in the theoretical line of fracture of the plate, the quantity P — D will be greater, while the Shearing Section remains the same. Joints would be proportionally increased, but the manufacturing difficulties would be increased out of proportion.

REMOVING RUST FROM BADLY PITTED STEEL

Apply to the surface two parts of Sodium Bisulphate and one part Common Salt. Moisten just enough to adhere to the surface. The mixture can be left on the plate until clean, or hastened by scraping off the mixture and wire brushing, and applying anew. Usually 24 hours will clean a badly rusted plate. When clean apply a coating of oil, so as to avoid the trouble again. This method is said to be cheaper and more effective than sand blasting.

PAINTING IRON AND STEEL SURFACES

A single coat of paint affords the greatest protection. Microscopic examination of a paint film, discloses that upon a second application of paint to a painted surface that the undercoat is partly redissolved and fresh cellular cavities are opened up, and the second coat has made the first coat more porous than originally. A single thick coat affords the maximum protection, the gradual oxidation of the solvent affording protection and preventing the formation of empty spaces in the coating.

We have incorporated various tables in the text of this catalogue at appropriate places, and in order to bring tabulation to a complete state as far as might be required generally by the rivet user we furnish the following.

TABLE OF DECIMALS AND COMMON FRACTIONS

32ds	64ths	Decimals	Fraction	32ds	64ths	Decimals	Fraction
....	1	.015625	....	....	33	.515625	....
1	2	.03125	....	17	34	.53125	....
....	3	.046875	....	....	35	.546875	....
2	4	.0625	1/16	18	36	.5625	9/16
....	5	.078125	....	....	37	.578125	....
3	6	.09375	....	19	38	.59375	....
....	7	.109375	....	....	39	.609375	....
4	8	.125	1/8	20	40	.625	5/8
....	9	.140625	....	....	41	640625	....
5	10	.15625	....	21	42	.65625	....
....	11	.171875	....	....	43	671875	....
6	12	.1875	3/16	22	44	.6875	11/16
....	13	.203125	....	....	45	.703125	....
7	14	.21875	....	23	46	.71875	....
....	15	234375	....	....	47	.734375	....
8	16	.25	1/4	24	48	.75	3/4
....	17	265625	....	....	49	.765625	....
9	18	.28125	....	25	50	.78125	....
....	19	.296875	....	....	51	.796875	....
10	20	.3125	5/16	26	52	.8125	13/16
....	21	.328125	....	....	53	.838125	....
11	22	.34375	....	27	54	.84375	....
....	23	.359375	....	....	55	.859375	....
12	24	.375	3/8	28	56	875	7/8
....	25	390625	....	....	57	.890625	....
13	26	.40625	....	29	58	.90625	....
....	27	421875	....	....	59	.921875	....
14	28	.4375	7/16	30	60	.9375	15/16
....	29	.453125	....	....	61	.953125	....
15	30	.46875	....	31	62	.96875	....
....	31	.484375	....	....	63	984375	....
16	32	.5	1/2	32	64	1.	....

Cut 96.

United States Standard Gauge for Sheet and Plate Iron and Steel.

Gauge Number	Thickness in Fractions of an Inch	Thickness in Decimals of an Inch	Approximate Thickness in Millimeters	Weight per Square Foot in Pounds Iron	Weight per Square Foot in Pounds Steel	Weight per Sq. Meter in Kilograms Steel
0000000	1/2	.5	12.70	20.	20.4	99.601
000000	15/32	.46875	11.91	18.75	19.125	93.376
00000	7/16	4375	11.11	17 50	17.85	87.151
0000	13/32	.40625	10.32	16 25	16.575	80.926
000	3/8	.375	9.53	15.	15.3	74.701
00	11/32	34375	8.73	13.75	14.025	68.476
0	5/16	.3125	7.94	12.50	12.75	62.251
1	9/32	.28125	7.14	11.25	11.475	56.026
2	17/64	.265625	6.75	10.625	10.8375	52.913
3	1/4	.25	6.35	10.	10.2	49.800
4	15/64	.234375	5.95	9 375	9 5625	46.688
5	7/32	.21875	5.56	8.75	8.925	43.575
6	13/64	.203125	5.16	8.125	8.2875	40.463
7	3/16	.1875	4.76	7.5	7.65	37.350
8	11/64	.171875	4.37	6.875	7.0125	34.238
9	5/32	.15625	3.97	6.25	6.375	31 125
10	9/64	.140625	3.57	5.625	5.7375	28.013
11	1/8	.125	3.18	5.	5.1	24.900
12	7/64	.109375	2.78	4.375	4.4625	21 788
13	3/32	.09375	2.38	3.75	3.825	18.675
14	5/64	.078125	1 98	3.125	3.1875	15.563
15	9/128	.0703125	1.79	2.8125	2.86875	14 006
16	1/16	.0625	1.59	2.5	2.55	12.450
17	9/160	.05625	1.43	2.25	2.295	11.205
18	1/20	.05	1.27	2	2.04	9.960
19	7/160	.04375	1.11	1.75	1.785	8.715
20	3/80	.0375	0.953	1.50	1.53	7.470
21	11/320	.034375	0.873	1.375	1.4025	6.848
22	1/32	03125	0.794	1.25	1.275	6.225
23	9/320	.028125	0.714	1.125	1 1475	5.603
24	1/40	.025	0.635	1.	1.02	4.980
25	7/320	.021875	0.556	.875	8925	4.358
26	3/160	.01875	0.476	.75	.765	3.735
27	11/640	.0171875	0.437	.6875	70125	3.424
28	1/64	.015625	0.397	.625	.6375	3.113
29	9/640	.0140625	0.357	.5625	57375	2.801
30	1/80	.0125	0.318	.5	.51	2.490
31	9/640	.0109375	0.278	.4375	44625	2.179
32	13/1280	.01015625	0.258	.40625	414375	2 023
33	3/320	.009375	0.238	.375	.3825	1.868
34	11/1280	.00859375	0.218	.34375	350625	1.712
35	5/640	.0078125	0.198	.3125	.31875	1.556
36	9/1280	.00703125	0.179	.28125	286875	1.401
37	17/2560	.006640625	0.169	.265625	.2709375	1.323
38	1/160	00625	0.159	.25	.255	1 245

Cut 97.

THICKNESS

	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/16	1 1/8	1 3/16	1 1/4	1 5/16	1 3/8	1 7/16	1 1/2	1 9/16	1 5/8	1 11/16	1 3/4	1 13/16	1 7/8	1 15/16	2
1/16	.01																															
1/8	.02	.05																														
3/16	.04	.07	.11																													
1/4	.05	.10	.15	.20																												
5/16	.06	.12	.18	.25	.31																											
3/8	.07	.15	.22	.29	.37	.44																										
7/16	.09	.17	.26	.34	.43	.52	.60																									
1/2	.10	.20	.29	.39	.49	.59	.69	.79																								
9/16	.11	.22	.33	.44	.55	.66	.77	.88	.99																							
5/8	.12	.25	.37	.49	.61	.74	.86	.98	1.10	1.23																						
11/16	.13	.27	.40	.54	.67	.81	.94	1.08	1.21	1.35	1.48																					
3/4	.15	.29	.44	.59	.74	.88	1.03	1.18	1.33	1.47	1.62	1.77																				
13/16	.16	.32	.48	.64	.80	.96	1.12	1.28	1.44	1.60	1.75	1.91	2.07																			
7/8	.17	.34	.52	.69	.86	1.03	1.20	1.37	1.55	1.72	1.89	2.06	2.23	2.41																		
15/16	.18	.37	.55	.74	.92	1.10	1.29	1.47	1.66	1.84	2.02	2.21	2.39	2.58	2.76																	
1	.20	.39	.59	.79	.98	1.18	1.37	1.57	1.77	1.96	2.16	2.36	2.55	2.75	2.95	3.14																
1 1/16	.21	.42	.63	.83	1.04	1.25	1.46	1.67	1.88	2.09	2.29	2.50	2.71	2.92	3.13	3.34	3.55															
1 1/8	.22	.44	.66	.88	1.10	1.33	1.55	1.77	1.99	2.21	2.43	2.65	2.87	3.09	3.31	3.53	3.76	3.98														
1 3/16	.23	.47	.70	.93	1.17	1.40	1.63	1.87	2.10	2.33	2.56	2.80	3.03	3.26	3.50	3.73	3.96	4.20	4.43													
1 1/4	.25	.49	.74	.98	1.23	1.47	1.72	1.96	2.21	2.45	2.70	2.95	3.19	3.44	3.68	3.93	4.17	4.42	4.66	4.91												
1 5/16	.26	.52	.77	1.03	1.29	1.55	1.80	2.06	2.32	2.58	2.83	3.09	3.35	3.61	3.87	4.12	4.38	4.64	4.90	5.15	5.41											
1 3/8	.27	.54	.81	1.08	1.35	1.62	1.89	2.16	2.43	2.70	2.97	3.24	3.51	3.78	4.05	4.32	4.59	4.86	5.13	5.40	5.67	5.94										
1 7/16	.28	.56	.85	1.13	1.41	1.69	1.98	2.26	2.54	2.82	3.10	3.39	3.67	3.95	4.23	4.52	4.80	5.08	5.36	5.65	5.93	6.21	6.49									
1 1/2	.29	.59	.88	1.18	1.47	1.77	2.06	2.36	2.65	2.95	3.24	3.53	3.83	4.12	4.42	4.71	5.01	5.30	5.60	5.89	6.19	6.48	6.77	7.07								
1 9/16	.31	.61	.92	1.23	1.53	1.84	2.15	2.45	2.76	3.07	3.37	3.68	3.99	4.30	4.60	4.91	5.22	5.52	5.83	6.14	6.44	6.75	7.06	7.36	7.67							
1 5/8	.32	.64	.96	1.28	1.60	1.91	2.23	2.55	2.87	3.19	3.51	3.83	4.15	4.47	4.79	5.11	5.42	5.74	6.06	6.38	6.70	7.02	7.34	7.66	7.98	8.30						
1 11/16	.33	.66	.99	1.33	1.66	1.99	2.32	2.65	2.98	3.31	3.64	3.98	4.31	4.64	4.92	5.30	5.63	5.96	6.30	6.63	6.96	7.29	7.62	7.95	8.28	8.61	8.95					
1 3/4	.34	.69	1.03	1.37	1.72	2.06	2.41	2.75	3.09	3.44	3.78	4.12	4.47	4.81	5.15	5.50	5.84	6.18	6.53	6.87	7.22	7.56	7.90	8.25	8.59	8.93	9.28	9.62				
1 13/16	.36	.71	1.07	1.42	1.78	2.14	2.49	2.85	3.20	3.56	3.91	4.27	4.63	4.98	5.34	5.70	6.05	6.41	6.76	7.12	7.47	7.83	8.19	8.54	8.90	9.25	9.61	9.97	10.32			
1 7/8	.37	.74	1.10	1.47	1.84	2.21	2.58	2.95	3.31	3.68	4.05	4.42	4.79	5.15	5.52	5.89	6.26	6.63	6.99	7.36	7.73	8.10	8.47	8.84	9.20	9.57	9.94	10.31	10.68	11.04		
1 15/16	.38	.76	1.14	1.52	1.90	2.28	2.66	3.04	3.42	3.80	4.18	4.57	4.95	5.33	5.71	6.09	6.47	6.85	7.23	7.61	7.99	8.37	8.75	9.13	9.51	9.89	10.27	10.65	11.03	11.41	11.79	
2	.39	.79	1.18	1.57	1.96	2.36	2.75	3.14	3.53	3.93	4.32	4.71	5.11	5.50	5.90	6.28	6.68	7.07	7.46	7.85	8.25	8.64	9.03	9.42	9.82	10.21	10.60	11.00	11.39	11.78	12.17	12.57

To obtain the sheared area of holes two inches and less in diameter through stock two inches and less in thickness, find the diameter at the left and the thickness at the top. The intersection gives the sheared area.

Cut 98.

TABLES OF INCHES AND MILLIMETERS

1. Inches to Millimeters.

1 Inch	=	25.4001 mm.
2 "	=	50.8001
3 "	=	76.2002
4 "	=	101.6002
5 "	=	127.0003
6 "	=	152.4003
7 "	=	177.8004
8 "	=	203.2004
9 "	=	228.6005

2. Millimeters to inches.

1 Millimeter	=	0.03937 inches.
2 "	=	.07874
3 "	=	.11811
4 "	=	.15748
5 "	=	.19685
6 "	=	.23622
7 "	=	.27559
8 "	=	.31496
9 "	=	.35433

TABLE OF ROUGH EQUIVALENT MEASURES

Length, Inches.	Millimeters.	Length, Inches.	Millimeters.
1/8″	3.	1 3/4″	45.
3/16″	5.	1 7/8″	47.
1/4″	6.	2″	50.
5/16″	8.	2 1/2″	65.
3/8″	10.	3″	75.
7/16″	11.	4″	100.
1/2″	13.	5″	126.
5/8″	16.	6″	150.
3/4″	20.	7″	180.
7/8″	22.	8″	200.
1″	25.	9″	230.
1 1/8″	30.	10″	254.
1 1/4″	32.	11″	280.
1 1/2″	40.	12″	306.

RIVETS IN MILLIMETER SIZES, THEIR EQUIVALENTS IN INCHES AND NEAREST STOCK SIZES

MM.	Equivalent in Inches.	Nearest United States Size.
12	.47244	.500 = 1/2″
13	.51181	.500 = 1/2″
14	.55118	.5625 = 9/16″
15	.59055	.5625 = 9/16″
16	.62992	.625 = 5/8″
17	.66929	.6875 = 11/16″
18	.70866	.6875 = 11/16″
19	.74803	.750 = 3/4″
20	.78740	.8125 = 13/16″
21	.82677	.8125 = 13/16″
22	.86614	.875 = 7/8″
23	.90551	.875 = 7/8″
24	.94488	.9375 = 15/16″
25	.98425	1.0000 = 1″
26	1.02362	1.0000 = 1″
27	1.06299	1.0625 = 1 1/16″
28	1.10236	1.0625 = 1 1/16″
29	1.14173	1.125 = 1 1/8″
30	1.18110	1.1875 = 1 3/16″
31	1.22047	1.1875 = 1 3/16″
32	1.25984	1.250 = 1 1/4″
33	1.29921	1.250 = 1 1/4″
34	1.33858	1.3125 = 1 5/16″
35	1.37795	1.375 = 1 3/8″
36	1.41732	1.375 = 1 3/8″
37	1.45669	1.500 = 1 1/2″

United States Sizes.		
1/2″	=	.500
9/16″	=	.5625
5/8″	=	.625
11/16″	=	.6875
3/4″	=	.750
13/16″	=	.8125
7/8″	=	.875
15/16″	=	.9375
1″	=	1.0000
1 1/16″	=	1.0625
1 1/8″	=	1.125
1 3/16″	=	1.1875
1 1/4″	=	1.250
1 5/16″	=	1.3125
1 3/8″	=	1.375
1 1/2″	=	1.500

U. S. lengths vary by 1/16 = .0625 inches
Metric lengths vary by MM = .03937 inches

Convertable Elongation:—Rivet material has its elongation commonly measured in 8″ gage lengths. Many times its convenient to know what the probably elongation would have been in 2″, 4″, or 6″ gage lengths. It is necessary, in order to arrive at a comparison to have the records of elongation of the same material over two gage lengths.

A consideration of the stretching of a piece of rivet material is worth while, and a specific case gave, on a ten-inch gage length, marked off into 1″ sections the following results:—

Inch.....	1	2	3	4	5	6	7	8	9	10
Stretch...	20″	.21″	.22″	.25″	.30″	.52″	.52″	.28″	.27″	.23″
						*fracture.				

Fracture occured at the 6th inch, and the stretch in that inch was .52 inches, so that the elongation in % for that inch was 52%.

Taking different gage lengths, vis 2″, 4″, 6″, 8″, and 10″, we get for percentage elongation the following values:

Gage Length	= 2″	4″	6″	8″	10″
% Elongation	=52%	40.5%	35.7%	33.6%	31.0%

In stretching under a load a test piece of steel undergoes two types of stretching.

A. =A general extension proportional to the gage length.

B. =A local contraction, and extension independent of the length of the test piece, as exemplified by the necking in at fracture.

Thus elongation is composed of two parts, or A + B.

In order to formulate this condition:—

Let E = Total extension.
L = Gage length.
A = General extension which we will call b times L or bL.
B = Local Extension at Necking in which we will call "a."

Percentage elongation = 100 times E ÷ L.

And taking the values above we get:—

Percentage elongation = 100 (a ÷ L + b).

As the gage length is indefinitely increased this value approaches 100 b., as exemplified in the test case quoted above.

Local extension "a" is proportional to the square root of the A of the test piece, and thus we can say $a = c\sqrt{A}$.

Our formula now becomes

$$\text{Percentage elongation} = 100\left(\frac{c\sqrt{A}}{L} + b\right).$$

To get concrete results, and bearing in mind that it is necessary to have two tests on a material gaged in two different lengths in order to determine the probable results in another gage length.

A test of Rivet Rod gave 39.5% elongation in 4″, area of bar = 1.332.

A second test of this material gave 30.2% in 6″, area of bar = .953.

What would be the ELONGATION in 8″, on a bar of this material .500 area.

1st. Test, in above formula =
% Elongation = 39.5 = 28.8 c + 100 b.

2d Test, in above formula =
% Elongation = 30.2 = 16.1 c + 100 b.

Combining 1 and 2, algebraically we get: 9.3 = 12.7 c, or c = .732 and b = .184.

Having determined c and b values for this material we can estimate the probably elongation of the third test in 8″, as:

$$\text{Percentage Elongation} = 100\left(\frac{.732\,(\sqrt{.500})}{8} + .184\right)$$

% Elongation in 8″ = 24.9%

The elongation for this piece in a 2″ gage length would be:

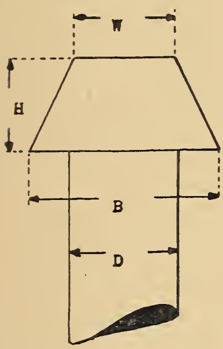
$$\text{Percentage Elongation} = 100\left(\frac{.732\,(.707)}{2} + .184\right)$$

$$= 44.2\%$$

SEVERANCE MANUFACTURING COMPANY STANDARD RIVET HEADS

Cone Head

CONE HEAD

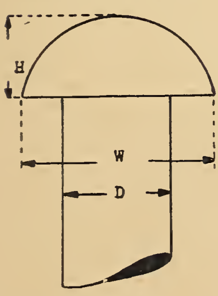


Cut 99.

Diameter D.	Width W.	Width B.	Depth or Height H.
1/2″	15/32″	7/8″	7/16″
9/16″	17/32″	63/64″	1/2″
5/8″	19/32″	1 3/32″	35/64″
11/16″	41/64″	1 13/64″	39/64″
3/4″	45/64″	1 5/16″	21/32″
13/16″	49/64″	1 27/64″	23/32″
7/8″	53/64″	1 17/32″	49/64″
15/16″	57/64″	1 41/64	53/64″
1″	15/16″	1 3/4″	7/8″
1 1/16″	1″	1 55/64″	15/16″
1 1/8″	1 1/16″	1 31/32″	63/64″
1 3/16″	1 7/16″	2 5/64″	1 3/64″
1 1/4″	1 11/16″	2 3/16″	1 3/32″
1 5/16″	1 15/16″	2 19/64″	1 9/64″
1 3/8″	1 9/32″	2 13/32″	1 13/64″
1 7/16″	1 11/32″	2 33/64″	1 17/64″
1 1/2″	1 13/32″	2 5/8″	1 5/16″
1 9/16″	1 15/32″	2 47/64″	1 23/64″
1 5/8″	1 33/64″	2 27/32″	1 27/64″

Button Head

BUTTON HEAD



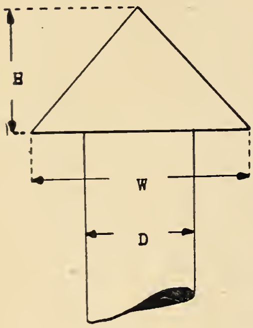
Cut 100.

Diameter D.	Width W.	Depth or Height H.
1/2″	7/8″	3/8″
9/16″	63/64″	27/64″
5/8″	1 3/32″	15/32″
11/16″	1 13/64″	33/64″
3/4″	1 5/16″	9/16″
13/16″	1 27/64″	39/64″
7/8″	1 17/32″	21/32″
15/16″	1 41/64″	45/64″
1″	1 3/4″	3/4″
1 1/16″	1 55/64″	51/64″
1 1/8″	1 31/32″	27/32″
1 3/16″	2 5/64″	57/64″
1 1/4″	2 3/16″	15/16″
1 5/16″	2 19/64″	63/64″
1 3/8″	2 13/32″	1 1/32″
1 7/16″	2 33/64″	1 5/64″
1 1/2″	2 5/8″	1 1/8″
1 9/16″	2 47/64″	1 11/64″
1 5/8″	2 27/32″	1 7/32″

S. SEVERANCE MANUFACTURING COMPANY STANDARD RIVET HEADS

Steeple Head

STEEPLE HEAD

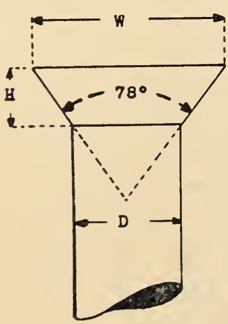


Cut 101.

Diameter D.	Width W.	Depth H.
1/2″	1″	9/16″
9/16″	1 1/8″	5/8″
5/8″	1 1/4″	45/64″
11/16″	1 3/8″	25/32″
3/4″	1 1/2″	27/32″
13/16″	1 5/8″	59/64″
7/8″	1 3/4″	63/64″
15/16″	1 7/8″	1 3/64″
1″	2″	1 1/8″
1 1/16″	2 1/8″	1 13/64″
1 1/8″	2 1/4″	1 17/64″
1 3/16″	2 3/8″	1 21/64″
1 1/4″	2 1/2″	1 13/32″
1 5/16″	2 5/8″	1 15/32″
1 3/8″	2 3/4″	1 35/64″
1 7/16″	2 7/8″	1 5/8″
1 1/2″	3″	1 11/16″
1 9/16″	3 1/8″	1 49/64″
1 5/8″	3 1/4″	1 53/64″

Flat Countersunk Head

FLAT COUNTERSUNK HEAD



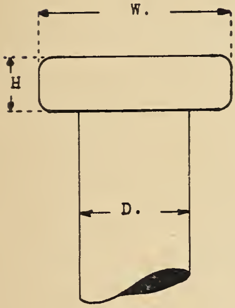
Cut 102.

Diameter D.	Width W.	Depth H.
1/2″	7/8″	1/4″
9/16″	63/64″	9/32″
5/8″	1 3/32″	5/16″
11/16″	1 13/64″	11/32″
3/4″	1 5/16″	3/8″
13/16″	1 27/64″	13/32″
7/8″	1 17/32″	7/16″
15/16″	1 41/64″	15/32″
1″	1 3/4″	1/2″
1 1/16″	1 55/64″	17/32″
1 1/8″	1 31/32″	9/16″
1 3/16″	2 5/64″	19/32″
1 1/4″	2 3/16″	5/8″
1 5/16″	2 19/64″	21/32″
1 3/8″	2 13/32″	11/16″
1 7/16″	2 33/64″	23/32″
1 1/2″	2 5/8″	3/4″
1 9/16″	2 47/64″	25/32″
1 5/8″	2 27/32″	13/16″

S. SEVERANCE MANUFACTURING COMPANY STANDARD RIVET HEADS

Flat Head

FLAT HEAD



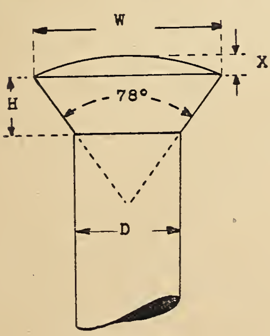
Cut 103.

Diameter D.	Width W.	Depth H.
1/2"	7/8"	1/4"
9/16"	63/64"	9/32"
5/8"	1 3/32"	5/16"
11/16"	1 13/64"	11/32"
3/4"	1 5/16"	3/8"
13/16"	1 27/64"	13/32"
7/8"	1 17/32"	7/16"
15/16"	1 41/64"	15/32"
1"	1 3/4"	1/2"
1 1/16"	1 55/64"	17/32"
1 1/8"	1 31/32"	9/16"
1 3/16"	2 5/64"	19/32"
1 1/4"	2 3/16"	5/8"
1 5/16"	2 19/64"	21/32"
1 3/8"	2 13/32"	11/16"
1 7/16"	2 33/64"	23/32"
1 1/2"	2 5/8"	3/4"
1 9/16"	2 47/64"	25/32"
1 5/8"	2 27/32"	13/16"

Oval Countersunk Head

The length of Countersunk Rivets includes the head to the top of Countersink.

OVAL COUNTERSUNK HEAD

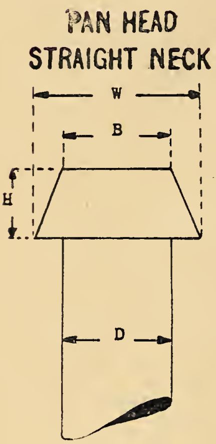


Cut 104.

Diameter D.	Width W.	Depth H.	Rounded Top Depth X.
1/2"	7/8"	1/4"	5/32"
9/16"	63/64"	9/32"	3/32"
5/8"	1 3/32"	5/16"	7/64"
11/16"	1 13/64"	11/32"	1/8"
3/4"	1 5/16"	3/8"	9/64"
13/16"	1 27/64"	13/32"	5/32"
7/8"	1 17/32"	7/16"	5/32"
15/16"	1 41/64"	15/32"	11/64"
1"	1 3/4"	1/2"	3/16"
1 1/16"	1 55/64"	17/32"	13/64"
1 1/8"	1 31/32"	9/16"	7/32"
1 3/16"	2 5/64"	19/32"	7/32"
1 1/4"	2 3/16"	5/8"	15/64"
1 5/16"	2 19/64"	21/32"	1/4"
1 3/8"	2 13/32"	11/16"	1/4"
1 7/16"	2 33/64"	23/32"	17/64"
1 1/2"	2 5/8"	3/4"	9/32"
1 9/16"	2 47/64"	25/32"	19/64"
1 5/8"	2 27/32"	13/16"	19/64"

S. SEVERANCE MANUFACTURING COMPANY STANDARD RIVET HEADS

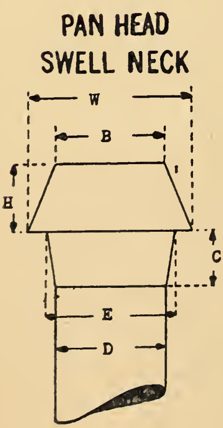
Pan Head Straight Neck



Cut 105.

Diameter D.	Width W.	Width B.	Depth H.
1/2″	13/16″	1/2″	3/8″
9/16″	29/32″	9/16″	13/32″
5/8″	1″	5/8″	7/16″
11/16″	1 3/32″	11/16″	15/32″
3/4″	1 3/16″	3/4″	1/2″
13/16″	1 1/4″	13/16″	17/32″
7/8″	1 5/16″	7/8″	9/16″
15/16″	1 13/32″	15/16″	19/32″
1″	1 1/2″	1″	5/8″
1 1/16″	1 9/16″	1 1/16″	21/32″
1 1/8″	1 5/8″	1 1/8″	11/16″
1 3/16″	1 3/4″	1 3/16″	23/32″
1 1/4″	1 13/16″	1 1/4″	3/4″
1 5/16″	1 15/16″	1 5/16″	25/32″
1 3/8″	2″	1 3/8″	13/16″
1 7/16″	2 3/32″	1 7/16″	27/32″
1 1/2″	2 3/16″	1 1/2″	7/8″
1 9/16″	2 1/4″	1 9/16″	29/32″
1 5/8″	2 11/32″	1 5/8″	15/16″

Pan Head Swell Neck



Cut 106.

Diameter D.	Width W.	Width B.	Depth H.	Depth of Neck C.	Diam'tr Neck at E.
1/2″	13/16″	1/2″	3/8″	1/4″	9/16″
9/16″	29/32″	9/16″	13/32″	9/32″	5/8″
5/8″	1″	5/8″	7/16″	5/16″	11/16″
11/16″	1 3/32″	11/16″	15/32″	11/32″	3/4″
3/4″	1 3/16″	3/4″	1/2″	3/8″	13/16″
13/16″	1 1/4″	13/16″	17/32″	13/32″	7/8″
7/8″	1 5/16″	7/8″	9/16″	7/16″	15/16″
15/16″	1 13/32″	15/16″	19/32″	15/32″	1″
1″	1 1/2″	1″	5/8″	1/2″	1 1/16″
1 1/16″	1 9/16″	1 1/16″	21/32″	17/32″	1 1/8″
1 1/8″	1 5/8″	1 1/8″	11/16″	9/16″	1 3/16″
1 3/16″	1 3/4″	1 3/16″	23/32″	19/32″	1 1/4″
1 1/4″	1 13/16″	1 1/4″	3/4″	5/8″	1 5/16″
1 5/16″	1 15/16″	1 5/16″	25/32″	21/32″	1 3/8″
1 3/8″	2″	1 3/8″	13/16″	11/16″	1 7/16″
1 7/16″	2 3/32″	1 7/16″	27/32″	23/32″	1 1/2″
1 1/2″	2 3/16″	1 1/2″	7/8″	3/4″	1 9/16″
1 9/16″	2 1/4″	1 9/16″	29/32″	25/32″	1 5/8″
1 5/8″	2 5/16″	1 5/8″	15/16″	13/16″	1 11/16″

CHAPTER XV

TRADE CUSTOMS AND INSTRUCTIONS FOR SPECIFYING RIVETS

In specifying rivets, care should be taken to give all necessary information,—length, diameter, style of head, number of pounds or number of kegs, with specification as to the weight of each keg. If possible, rivets of Standard sizes, such as indicated in various parts of this book should be used, and packages should be used to save delay and extras. A slight change in the type of head, the specification of an abnormal weight of keg may tend to cause unnecessary delay.

We aim to carry in stock:

Round (or Button) Head Structural and Bridge Rivets, packed in kegs of 250 pounds each to the following Standard Chemical and Physical requirements:

Chemical Properties

Carbon..........................08 to .12.
Manganese.......................30 to .50.
Phosphorous.....................040 or under.
Sulphur.........................045 or under.

Physical Properties

Tensile Strength. Pounds per square inch, 46000 to 56000.
Elongation in 8″. % 1400000 ÷ Tensile Strength.
25% to 30%

Cone Head Boiler Rivets packed in kegs of 200 pounds each to the following Standard Chemical and Physical requirements:

Chemical Properties

Carbon..........................08 to .12.
Manganese.......................30 to .50.
Phosphorous.....................040 or under.
Sulphur.........................040 or under.

Physical Properties

Tensile Strength, pounds per square inch, 45000 to 55000.
Elongation in 8″ % 1450000 ÷ Tensile Strength.
26% + to 32%.

We aim to carry a stock of dies and steel rivet bars to make promptly, Rivets for Ship Construction, Boiler Construction, Bridge Construction, etc., etc., with Heads of Standard Dimensions and meeting Standard Specifications.

Ship Rivets and Countersunk Head Rivets are usually made to order there being several types of heads as has been previously indicated. Pages 171, 172, 178 and 174 describe recommended Standard Heads.

We aim to carry in stock Steel Bars that have been inspected and approved by the Lloyd's Registry of Shipping, and of the American Bureau of Shipping, ready to make into Ship Hull Rivcts, as specified, promptly.

PRICES AND TERMS

Prices quoted, unless otherwise stipulated, are for immediate acceptance and are subject to change without notice.

Prices quoted are for base sizes, unless otherwise stated, and the standard lists of extras apply.

Special prices will be quoted on special or unlisted goods.

Terms of payment on all sales are net cash in thirty days, after date of Invoice, to one-half per cent. discount if paid within ten days from date of invoice.

Cash discount, when allowed, applies to the net amount of invoice, after freighr allowance has been adjusted.

Accounts not paid at maturity will be drawn on at sight, after due notice of our intention has been given.

AGREEMENTS

All material to be shipped by freight unless otherwise specified.

No allowance will be made for cartage.

All orders accepted and contracts entered into are subject to delays on account of strikes, fires, accidents, or other causes beyond our control.

CLAIMS

All defective or imperfect material will be replaced free of charge, f.o.b. our mill, but no claims for damages arising therefrom, loss of time, or materials will be allowed.

CANCELLATIONS

Cancellation of orders entered upon our books will be accepted only with our consent, and upon terms that will indemnify us against loss.

SHIPMENTS LOST OR DAMAGED

Our responsibility ceases as shippers upon obtaining signed bill of lading showing that shipment has been delivered to and accepted by the transportation company in good order.

Consignee should present claim to the transportation company for delay, loss or damages of goods in transit.

Consignee should see that expense bill bears notation in ink, endorsed by the transportation company's agent, when accepting a shipment on which loss or damage has occurred.

For guidance in specifying rivets the following tables of "Extras" are given, covering large and small rivets. Reference to the Base Price as currently quoted in Trade Papers is suggested, and correspondence invited by any prospective users of rivets. Current prices will be promptly quoted, with terms, deliveries, and conditions of sale, to any interested.

LARGE RIVET LIST

(Rivets ½ inch diameter and larger.)
Adopted October 15th, 1912,
Revised February 2d, 1920.

BASE SIZES

BOILER RIVETS, Standard Heads	Base price the 100 lbs.	$
STRUCTURAL RIVETS, Standard Heads	" " " "	$
SHIP RIVETS, Standard Heads	" " " "	$

Diameters, ¾″ to 1¼″ inclusive. Lengths 2″ to 5″ inclusive.
Packed in kegs or bags of 200 lbs. to 300 lbs. each.

STANDARD EXTRAS

	Extra the 100 lbs.
1—½″ and $\frac{9}{16}$″ diameters	$0.50
2—⅝″ and $\frac{11}{16}$″ diameters	.15
3—Rivets larger than 1¼″ diameter	.25
4—Lengths 1″ and shorter	.50
5—Lengths between 1″ and 2″	.25
6—Lengths over 5″	.25
7—Flat Head Rivets	.25
8—All Standard Countersunk Head Rivets	.25
9—Swell Neck Rivets	.25
10—Special Heads other than our regular Standards	.25
11—Annealing Rivets ½″ diameter and larger. (Our rivets are all made hot and do not need annealing except for special purposes)	.35
12—Rivets packed in 100 lb. packages	.25

13—We prefer not to break kegs, but if customer finds it is necessary to order less than 100 pounds of a size, add $1.00 flat for each size.
14—All Cone and Countersunk Head Rivets to be charged at Boiler Rivet price.
15—Cost of testing and inspecting, if any, to be at customer's expense.
16—High Carbon or Special Alloy Rivets, special extra price upon application.

RIVETS TO LLOYD'S SPECIFICATION

17—For Hulls. Add to the price of Ship Rivets	.10
18—For Boilers. Add to the price of Boiler Rivets	.15

DIRECTIONS FOR ORDERING

Rivets are divided into two classes as to size and are known as:—
LARGE RIVETS (½″ diameter and larger).
SMALL RIVETS ($\frac{7}{16}$″ diameter and smaller).

1. Grade of Rivets required ....
   (Boiler—Structural—Ship).
2. Type of Head ....
   Cone—Button—Pan—Steeple, etc.
3. Length ....
   Measure Countersunk Rivet to Top of CS. Others under head.
4. Diameter ....
5. Quantity packed in—size kegs ....
   Standard Kegs. Boiler 200 lbs. Structural and Ship 250 lbs
6. When needed ....
   Date
7. Shipment Routing ....
8. Special Markings of Kegs ....
9. Ordered by ....
10. Shipped to ....
11. Send shipping papers to ....
12. Send invoice to ....

THE S. SEVERANCE MANUFACTURING COMPANY

SMALL RIVET LIST

($\frac{7}{16}''$ diameter and smaller).

Adopted and Effective May 19, 1920

STANDARD HEADS ONLY

Old Standard Wire Gauge. Cents per pound in 200 pound kegs.

Rivets are made from scant sized wire so as to fit holes of their rated size.

Diameters	Min. Wire Diameter	LENGTHS															
		6–3¾	3½–2¼	2–1	⅞–¾	⅝–½	$\frac{7}{16}$	⅜	$\frac{11}{32}$	$\frac{5}{16}$	$\frac{9}{32}$	¼	$\frac{7}{32}$	$\frac{3}{16}$	$\frac{5}{32}$	⅛	$\frac{3}{32}$
$\frac{7}{16}$	.422	17	17	15	15½	16	17	18	19	20	20	...	...	...	...	...	...
⅜	.361	17	17	15	15½	16	17	18	19	20	20	...	...	...	...	...	...
$\frac{11}{32}$	.330	18½	17½	15½	16	16½	17	18	19	20	20	...	...	...	...	...	...
$\frac{5}{16}$	.300	18½	17½	15½	16	16½	18	18	19	20	20	...	...	...	...	...	...
No. 1	.288	19	18	16	16½	17	19	19	19	20	20	...	...	...	...	...	...
No. 2	.272	19	18	16	16½	17	19	19	19	20	20	20	21	...	...	...	...
No. 3	.249	19	18	16	16½	17	19	19	19	20	20	20	21	...	...	...	...
¼	.242	19	18	16	16½	17	19	19	19	20	20	20	21	21	...	...	...
No. 4	.230	22	20	17	17½	18	19	20	20	20	20	20	21	21	22	...	...
No. 5	.211	22	20	17	17½	18	20	20	20	21	22	22	23	23	24	24	25
No. 6	.195	22	20	17	17½	18	20	21	21	22	22	23	24	25	25	25	26
$\frac{3}{16}$	.180	22	20	17	17½	18	20	21	21	22	22	23	24	25	26	27	28
No. 7	.172	....	....	17	17½	19	20	21	21	22	22	23	24	25	26	27	28
No. 8	.156	....	....	18	18½	19	21	22	22	23	23	24	25	26	27	28	29
No. 9	.141	....	....	19	19½	20	22	23	23	25	25	25	26	27	29	31	32
No. 10	.128	....	....	20	20½	21	23	25	27	29	30	30	32	35	37	39	40
No. 11	.113	....	....	21	21½	22	26	29	30	32	33	33	35	39	42	44	47
No. 12	.104	....	....	22	22½	23	28	31	32	34	36	37	38	43	47	52	57
No. 13	.090	....	....	26	26½	27	32	36	37	39	41	42	43	47	52	57	62
No. 14	.078	....	....	28	28½	29	37	42	47	52	54	57	60	60	62	65	67

5-64 (Min. Wire Diam. .074) same list as No. 14; 3-32 (.088) same as No. 13; 7-64 (.104) same as No. 12; 1-8 (.120) same as No. 11; 9-64 (.136) same as No. 9; 5-32 (.151) same as No. 8; 11-64 (.165) same as No. 7; 7-32 (.211) same as No. 5; 9-32 (.272) same as No. 2.

Intermediate lengths and diameters take list of nearest smaller size.

Rivets made from smaller wire than No. 14 will be quoted on application.

Standard Heads are Round—Wagon Box—Truss—Cone—Flat—Flat Countersunk and Pan Heads. All other shaped heads and Headless, Shoulder and Pointed Rivets are special on which prices will be quoted on application.

The above list applies only on BULK QUANTITIES in 200 lb. kegs. Other packages take the following List Extras:

Packed in	100	Pound	Kegs	add	1 Cent	to above	List.
" "	50	"	Boxes	"	3 Cents	" "	"
" "	25	"	"	"	4 "	" "	"
" "	5 or 10	"	"	"	5 "	" "	"
" "	1	"	"	"	8 "	" "	"

Special finishes such as Metallic Coating, Plating, Tumbling Bright or Polishing after annealing quoted on application. When "Tinned" Rivets are ordered Metallic Tinned are furnished.

THE S. SEVERANCE MANUFACTURING COMPANY,
GLASSPORT, PENNSYLVANIA.

PRESS OF
JAMES McMILLIN PRINTING COMPANY
PITTSBURGH, PA.